

# JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION

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## Wartime Water Works Maintenance in Britain

*By A. Carrington Wildsmith*

UPON the outbreak of war in the autumn of 1939, and in anticipation of possible immediate and heavy air raids on the civil population of Great Britain, water authorities put into action plans for ensuring, as far as possible, the continuance of a safe and adequate water supply. Briefly, the problems of the authorities were: (1) to obtain rapid and accurate information of any damage ("incident") to mains and works; (2) to shut off, as soon as possible, any broken mains; (3) to minimize disturbance and loss of working time, through loss of pressure or water supply, and to provide drinking water; and (4) to repair the damage. These problems will be discussed in the following pages.

In Great Britain, the general A.R.P. Service, under the control of the town clerk, or other authority establishes in each area a Central Control. At this center all reports concerning air raid incidents are received and sorted. Messages are sent in by police, air raid wardens, etc., reporting incidents on their patrols. A representative of the water authority attends at the center, or the water authority maintains a control center for its own use, and incidents concerning it are passed on from the Central Control. In many authorities the distribution section has been the "Cinderella" of the service, but as heavy bombing is invariably on the cities and not on the outlying headworks, the distribution staff becomes vitally important. It follows therefore that its members should figure prominently in the control arrangements.

A record of British water works maintenance experience furnished to John H. Murdoch Jr., Pres., Pennsylvania Water Works Assn., by A. Carrington Wildsmith, Northern Dist. Engr., Manchester Corporation Water Works, England, and published here through the courtesy of Mr. Murdoch.

In the control room itself there should be complete plans of all the mains in the area (skeleton plans are good enough), with sizes and valve positions prominently marked, together with "key" firms; charts of names and addresses and telephone numbers of all personnel likely to be needed in any emergency, together with similar data concerning the key men of other adjoining authorities and their control services. The key firms should be informed if any incident affects their supply. Generally telephones have been used for sending reports, with messengers as a standby. Telephone services have proved more reliable than was expected and the provision of lines out, via different exchanges, reduces the hazard.

The reports state the exact position of the incident, time of origin, whether inside or outside premises, other services affected and obstructions. Provision is made for indicating the presence of war gas (not used thus far). Messages should be passed to Central Control as quickly as possible. The great weakness of control systems is the sometimes unaccountable delay in the transmission. A warden cannot usually tell a severe break on a small main from a small fracture on a large one, yet the difference to the authority is serious. In other cases the damage done by the escaping water from a large main can be more than that resulting from the bomb explosion itself and there have been instances where large volumes of water have penetrated basement shelters, to the peril of the occupants trapped therein. It is not realized by the layman that it takes considerable time to operate the several valves that govern large mains of 24 in. or more in diameter and that water is escaping for considerably longer than the transmission time for messages.

### Outside Staff

Messages sent out will be in the first case to district inspectors or turncocks. Most authorities in Britain have found it necessary to increase these staffs.

Extra men have been engaged and given intensive instruction, some authorities providing them with motor transport. One authority considers that bicycles provide the best means of transport if the district is kept small, from say half-a-square mile in the city to two square miles in outer suburbs. The men are usually allowed to stand by in air raid shelters at their homes, the shelters having telephone extensions. On receiving a call from the control a turncock goes to the incident. If the main is small he operates the valves himself and returns home for further duty. At the depot a number of men and a lorry stand by on a regular rota. They are sent out by the control staff on receipt of a message from the turncock that the shut-off is too large for him to manage by himself, or if to the staff it appears from the site of the incident that extra help will be needed. Dam-

age to pumping stations is covered by calling out the pumping engineer and commencing the necessary change-over.

Bombs are usually released in sticks of five or six at a time, and one area may have several incidents while the next is clear. The incidents can then be divided between the two turncocks. Day raiding in force has become hazardous to the enemy and it has been found that daylight incidents can be covered by the ordinary day routine, the special control arrangements operating during blackout hours. In any case, gradual calling up of technicians for the services is reducing the numbers available for control duty.

To minimize the inconvenience due to a shut-off, a key works should arrange for an alternative connection from another main—it will be money well spent. Inconvenience to the general consumer can be reduced by inter-connecting mains wherever possible and fitting control valves at all branches and cross-overs. The town with two or three trunk mains from the reservoirs to the city will be better off than the place with one. Inter-connections with adjoining systems should be arranged on a mutual aid basis. Even a small alternative supply is better than none at all and may at least afford drinking water. These inter-connections have proved very useful. Where only a small area is affected people can usually obtain drinking water from the next street or so, on their own initiative, but larger areas have to be supplied by mobile tanks of up to a thousand gallons capacity. Generally during a raid people are in shelter and little drinking water is used, the first aid services having their own water carriers. The tank system may have to be extended greatly if the only trunk main to a city is severed in many places, as sometimes happens.

No attempt is made to carry out repairs to outside water mains during a night raid. Where lights are allowed they are too dim to be of any use for other than rescue or first aid work. Some services, such as telephones, can work inside portable canopies erected over the joint hole, but with water services this is not possible. A break small enough to be dealt with in this manner can be left till daylight—a big break has too large an area to cover over; furthermore, a clear picture of what has to be done cannot be formed until all reports have come in and been collated. This is done by the control staff which sends men to the most urgent jobs and prepares a list of the incidents, to be handed to the district engineers concerned for inspection and supervision. The number of incidents dealt with in one night of heavy raiding may be a hundred or more and it will be seen that control work is no sinecure. In the authority with which the author is connected control is carried out by one engineer with three assistants (usually clerical) and at least one of each team, usually the engineer, is familiar with the whole routine of the distribution section. This system

has served efficiently an urban area of about 40 sq.mi. and containing many hundreds of miles of piping up to 44 in. in diameter.

### Main Repairs

There can be no hard and fast rules about repairs to bomb-damaged water mains. They have one thing in common—that when you see each crater containing a jumble of broken pipes, cables and other debris it seems impossible that order can ever come from such chaos. Nevertheless the seemingly hopeless task must be attempted, and quickly too, for the following night may bring another raid with its further crop of incidents. There is not much daylight in winter and night work on repairs has been mostly impracticable, for lights have to be extinguished on receipt of a raid warning. Where this occurs several times in a night, or the period is long, it merely results in wasted time and poor output the following day through loss of sleep.

It is usually difficult to tell the extent of the damage, which may extend well beyond the limits of the crater. The ground wave from the explosion seems to “whip” the main and sometimes causes a series of fractures for perhaps ten yards or more from the edges of a 25-foot crater. An examination of the apparent limit of the ground disturbances will afford a clue and the author has found that there is often no damage beyond the limits of the surface cracks. There is an exception in the case of parachute mines which are tubular containers filled with high explosive and weighing up to two tons, with parachutes attached. These mines explode on the surface of the ground, causing a tremendous blast but a very shallow crater. They have made fractures well beyond the limit of the surface cracks.

If the crater is a small one, caused by a light bomb, the main can be permanently repaired, as for an ordinary fracture. Where the crater is large and the damage extensive, the main is cut off and capped on each side of the crater. If the main is fed from both ends it is then left until the City Engineer's Department has cleared up the site, but if it is fed from one end only the crater must be bridged with a temporary pipe. For domestic property and mains up to 6 in. in diameter, a 1-inch lead pipe is good, while larger sizes are dealt with by affixing steel or asbestos-cement piping with flexible joints of the “Dresser” type. Mains 15 in. or more in diameter can be temporarily repaired with Victaulic or Dresser-coupled steel tapers and pipes of smaller diameter, but, except in the case of very large craters of great depth, this is definitely not worth while and it is better to complete a permanent repair, supporting the pipes on piers or diverting around the crater. The amount of labor used in putting in the temporary main is little less and the work has still to be done again at a later date. This applies particularly to the largest mains. The author

has made use of a petrol-electric mobile crane of three tons capacity and powered by a 10 hp. Ford engine. This can make short runs on its own power but is towed to the job. Due to the electric drives it can handle material with the utmost precision. It was purchased at the beginning of the war and has been worth its weight in gold on these bomb incidents. Referring once more to temporary mains it may be necessary to cover a whole area and not merely separate incidents. At least one town, unlucky enough to have few control valves and a closely built-up center, suffered so severely that several miles of temporary asbestos and steel piping were laid in the street channels, alongside the kerbs, ramps being arranged at the street crossings. Following very heavy raids it is possible to obtain the help of technicians and labor from neighboring authorities, and the military, too, have supplied labor.

Usually there is nothing in a crater to back up timber if it is necessary to trench into the bottom. The sides of a crater in poor ground, water-logged because of the fracture, continually fall in on the work, and we have had to fill in ground back of the timbers to brace them.

After a heavy raid, when many streets are blocked, traffic routes are in chaos until the police have charted up the through ways, and it is well if all private traffic is banned from the bombed areas. Even the priority label "Repair Party—Water Works" cannot prevent delays in getting men and materials to the incidents; every effort is made therefore to get all stores out to the jobs as early as possible and at the same time arrangements are made for bringing in the men at night.

### Experience With Delayed Action Bombs

On occasions very large bombs have been used, fitted with short delay fuses. These bombs have penetrated about 30 ft. or more, and, sometimes weighing more than a ton, they have caused tremendous underground disturbance and serious fractures in the surface water mains. One of these fell near a water main 26 in. in diameter, breaking several pipes and disturbing nearby joints. A large bomb fell in the center of a road containing water mains 15 in., 7 in. and 4 in. in diameter, with a 3 in. diameter branch main off the 4-inch line. The explosion caused a crater over 70 ft. across and filled with collapsed houses and road material. The line of the smaller mains was just inside the crater and the 15-inch through the center; there was severe road cracking for some distance on either side. The smaller mains were stopped off at the furthest cracks and the 3-inch main fed by about 30 yd. of lead pipe from the nearest 4-inch stopper. The large main was cut at the furthest cracks and tapered to 12 in. in diameter. Special vitaulic jointed steel tapers and pipes down to 6 in. in diameter were laid round the crater. The main was sterilized with sodium hypochlorite and

charged. A week later when the footpath [sidewalk] had been cleared, all three mains were permanently diverted round the crater. The work was hampered by the presence of a delayed action bomb some few yards from the site, which could not be moved till next day and prevented lorries from approaching. The military eventually extracted the fuse and removed the bomb, casually pulling it out of the hole with a lorry and chain. It proved to weigh about 600 lb. and had penetrated 10 ft.

On another occasion a large delayed action bomb was reported alongside a 30-inch water main. It did not explode and when the bomb disposal squad had reached a depth of 20 ft., it had not yet been found. Eventually it was found at 27 ft. where it had curved until it was directly beneath the main. It was drawn to the surface and put out of action. This bomb also weighed over 600 lb. During operations the main had not been shut off owing to its importance, the men standing by at the nearest valves. Bombs are not removed unless absolutely necessary, owing to the danger to the crews; they are usually detonated if the damage is not likely to affect an essential service.

A delayed action bomb weighing over 750 lb. fell alongside a 36-inch cast-iron water main in a heavily concreted main road. The impact tore off the fins of the bomb, which were left on the road surface, while the bomb lodged just below. On excavating, the bomb was found touching the side of the main. The author and his assistant visited the site (under the firm conviction that the bomb was a "dud"). It was of the thin cased type, and somewhat dented by its passage through the concrete surface. It certainly looked harmless enough and it was difficult to realize that the greater part of its weight was high explosive. The bomb disposal officer decided that it was too dangerous to move it or to extract the fuse and it was decided to detonate, arranging things so as to cause the least possible damage to the water main. A sandbag wall was built round the opening to protect the buildings but delays on other services held up the job and the event was postponed till next dawn. The main was shut off but left charged over a distance of about a mile, the lower shut-off valves being only 20 yd. down from the bomb. At midnight the bomb detonated on its own time fuse! Thanks to the sandbag wall the surrounding property was undamaged, but the main received the full force of the blast and was completely shattered. The two ends of the break were covered in road debris and one end jammed with a piece of concrete 8 in. thick and about 3 sq.yd. in area which had gone up in the air and fallen edge up, into the pipe. The crater was in sand, turned to running sand by the escaping water, of which there was still a great deal trapped in the upstream length of the main by the pile of debris. Two 500-gpm. pumps were put on to get rid of the water but the strainers were continually clogged by the sand

and it was some time before actual clearing could start. A trench had to be timbered and filled in behind the timbers, and the crane used to remove the debris in skips, while men had to be sent down the pipe to bring out the sand and stones which covered the invert for many yards. A piece of the bomb casing was found inside the pipe. One 12-foot pipe length was smashed to small pieces and the two adjoining pipes, into larger fragments. No sewers were broken but sterilization was carried out carefully because of the amount of debris that had been washed down the main.

### Sterilization Practice

Since the outbreak of war the Ministry of Health has ordered the sterilization of all drinking water, and owing to its cheapness and ease of application chlorination is practically universal. The method varies, some authorities working on the least possible dose to give a residual following the standard contact period, others maintaining a measurable residual in any part of the system, risking taste troubles in the interests of security. It has been found that once people have realized the value of the precautions they will tolerate some taste. Additionally some authorities increase the dosage when enemy action develops. This precaution proved extremely valuable in the case of one town on a river estuary. A heavy fire raid developed and the fire brigade ran a supply from the river, relayed through several sets of mobile pumps to the town. The driver of the second set of pumps, having a spare inlet on his pump, connected it to a nearby hydrant. The pump pressure overcame that in the mains and river water was pumped into the main. The control received a message that the drinking water tasted salty. The chlorine dose was immediately increased still further and the engineering staff went over the whole of the brigade piping to find the cause. Despite the fact that the river water was fouled with trade wastes and sewage the high chlorine residual prevented any ill effects.

The sterilization of bomb-damaged mains presents some problems. Small mains are easily dealt with by inserting an appropriate amount of bleaching powder into the pipes before jointing, or pumping hypochlorite through a hydrant with a hand force-pump, while charging the main, 40 to 60 ppm. being a usual dose. After a suitable period the main is flushed through the hydrants and put into use. Larger mains are more difficult—because of their importance they should be in service as soon as possible, yet thorough sterilizing is necessary and the emptying, flushing and subsequent recharging takes time and runs off huge quantities of water from reservoirs possibly already lowered by losses through breaks and fires. Mobile chlorinators are in common use, but the author does not consider their use on rush jobs worth while. To dose a mile of 30-inch main to 60 ppm. will take about 7 hr. through a plant delivering 350 lb. a

day of chlorine, with an injector pressure of 100 to 120 psi. Under most conditions this would necessitate the use of a pump, for which about 10,000 gal. of suction water will have to be provided, apart from the insertion of delivery cocks into the main. The author's opinion is that the easiest and quickest way is to use hypochlorite solution or bleaching powder in all circumstances, keeping the chlorine plants for use as continuous chlorinators in an emergency. The hypochlorite can be pumped in as for smaller mains, or poured down hydrants en route, before charging; the bleaching powder can be mixed to a cream and poured down hydrants or inserted before jointing, as much of the pipe as possible being "whitewashed" with the cream. The author has not heard of a case where bad results have followed the above procedure and the London Metropolitan Water Board recently made a statement that there had not been a single case of water-borne infection following air raids, in the area controlled by the Board. One point is most important—that is the removal of the sediment from the pipe invert. This may be soaked in sewage and, if left, forms a hard layer through which the sterilizing agent cannot pass. The water might then show a good residual and perhaps weeks later be in a dangerous bacteriological condition. In one case a large main was broken by two craters about 100 yd. apart, and the sewers were also shattered. Both craters filled with a mixture of water and sewage and had to be pumped out. For many hours the short length of main acted as a bypass to the sewer and when ready for repairs showed a deposit of sand and sewage two inches thick on the pipe invert. This was cleaned out with a drag scraper and winch, and the main chlorinated twice, the chemist being then quite satisfied with the results of his analysis.

### Water for Fire Fighting

The same methods of maintaining general supplies will prove useful in the case of water for fire fighting. Here the problem is complicated by the large quantities and the pressure required. Damage to the chief fire mains in the high pressure system may mean wholly pumped supplies being used and with the extensive fires resulting from incendiary attack the quantity pumped pulls down the pressure still more. Despite regulations to the contrary, private firms and unskilled fire teams will not hesitate to connect a powerful pump to the nearest available hydrant and hasty operation may result in a broken main. There is little doubt that pressures have been considerably reduced by careless operation. A walk round the area during a heavy fire raid has in the past told its own tale of hundreds of leaking hydrants (the majority of British water works still use the ball type, in a surface box, which is particularly liable to damage), of hydrants plugged

open, with pump suction hoses in the open boxes and the "surplus" water running down the gutter, while round the corner the unfortunate user of a standpipe and hose complains bitterly of the lack of mains pressure. The position is now eased by the use of portable canvas dams, in conjunction with steel or concrete tanks at strategic points, from which the pumps can draw their supplies and which may be filled by hose and standpipe, avoiding direct draw-off from the mains and waste of water. These dams hold from 5,000 to 10,000 gal. but to provide against complete failure additional storage tanks have been constructed in sheet piling or reinforced concrete, or of puddle lined excavations in parks and spaces. These hold 150,000 to 250,000 gal. each. Very large reserves are stored in the basements of demolished buildings, which have been lined with a skimming of cement mortar placed by hand or cement-gun. Some of these basements hold 1 mil.gal. or more and are connected to each other and the city canals by temporary steel piping fitted with pump unions. These reservoirs are chlorinated at intervals to prevent odor, but no connection is allowed between any static supply of this nature, or its piping, and the street mains. Sprinkler systems connected to domestic mains may not utilize such water, but must run an entirely separate system.

These measures will reduce the peak load on the mains, but even so losses will be high. Following a heavy raid, with fire and high explosive bombs, the minimum night flow on one system rose from the normal 40,000 gph. to 150,000 gph. and remained near this figure for several days. The leakages were therefore 110,000 gph. for the district served. Much of this was accounted for by broken hydrants, the remainder by a few sprinkler supplies leaking undetected in demolished buildings and many hundreds of severed lead services to ruined houses.

### Protection Against Sabotage

Probably the vigorous anti-fifth column measures taken by the British Government on the outbreak of war have accounted for the freedom from sabotage on British water works. Nevertheless it is guarded against by measures which must remain undisclosed. Short of possession of the reservoirs or pumping stations by a substantial invading force, it is probable that little damage could be caused to a water works if proper measures for the detection of unauthorized persons are taken. The weakest point would be the sterilizing plants where these are a necessity and not a refinement, but as these are compact and easily guarded the precautions are obvious. It is very necessary that the whole staff, including any extra night guards, should be familiar with the officials normally visiting the plant. It is very easy for a new watchman, for instance, to be bluffed by a good appearance

and authoritative manner on the part of a stranger visiting the works. Even if the visitor is a familiar works figure the check on identity should not be omitted.

### Protection of Buildings

The effect of bombing is probably well known to many U.S. Engineers. Surprisingly, the ordinary standard usual in well-built property is capable of considerable resistance to comparatively near misses, particularly if the building is of reinforced brickwork, or has reinforced concrete or steel framing. The usual light incendiary bomb will not penetrate a 2-inch layer of good concrete and if a building has a flat roof of timber, it is probable that such a layer, lightly reinforced, could be put on over the waterproofing without overstressing the beams. Some buildings erected here since the war show a reinforced brick-work wall 14 in. thick, with windows forming a horizontal line about the level of the machinery. The windows are standard heavy steel casements, glazed with wired glass in 12 by 18 in. panes. On a raft foundation, with blast walls protecting the entrances, and a reinforced concrete roof, this design gives complete protection from blast and splinters for bombs of 500 to 750 lb. falling 100 ft. away, and even at much closer distances, and lends itself to effective "modern" treatment of the elevation. Sandbagging should be avoided. The bags soon rot and often the disposal of many tons of sand is a real problem.

To close the paper the author would like to say something of the control staff and the control room. To take the least sentimental view, the control staff is a valuable instrument in the service of the authority. The staff should therefore have at least the same protection as the most important parts of the plant. It is useless to protect the pumping station if the control staff can be wiped out by the lightest bomb. The concentration and nervous strain demanded by control work can be greatly eased if the staff feel that they are well protected, and have a fair degree of comfort. Under such circumstances an over-imaginative person will perform administrative duties with steadiness that would be quite beyond his powers if the protection was inadequate. Unlike outside staffs, the control staff has not the relief of violent physical action.

Finally the author would say that it is the earnest hope of engineers in Britain that our friends in the United States may never experience the trials we have undergone here, despite the grave fact that your country is now at war with the Axis powers, but we can be sure that whatever may be before any of us, there is no problem arising from these conditions that will not be solved by the ingenuity and determination expected of our profession by those whom we serve.



## **New York State Mutual Aid Plan for Water Service In Case of Emergencies**

*By Anselmo F. Dappert*

**T**HE New York State Mutual Aid Plan for Water Service in Case of Emergencies was formulated by a committee of water works officials appointed by the Mayors' Conference and State Department of Health at the request of Governor Lehman. The Mutual Aid Committee, which still continues in existence, is composed of the following: A. H. Rogers, Garden City, Chairman; and Leonard A. Bergman, Buffalo; John G. Copley, Elmira; E. J. Rowe, Wellsville; H. D. Darrow, Kingston; Thomas H. Wiggin, New York; George D. Norcom, New York; and E. P. Stewart, Syracuse. This committee formulated the plan and is being kept advised as to the activities which are in progress. It stands ready to act upon any matter presented.

An advisory committee was also appointed and was consulted at the time the plan was in process of formulation. This committee still continues in existence, consisting of: C. A. Holmquist, State Dept. of Health, Albany; John J. Bourke, New York State Health Preparedness Com., Albany; A. P. Miller, U. S. Public Health Service, New York; Harry E. Jordan, American Water Works Association, New York; and W. W. Brush, *Water Works Engineering*, New York.

The plan as formulated was recommended to the Governor and approved by him on October 14, 1941. Briefly stated, the general objective is to prepare New York State municipalities to maintain adequate, effective and safe water service under any possible emergency that may arise, either as a result of war or from natural causes, and to achieve this state of preparation with the least possible delay. Simple of statement, this general objective will require much work on the part of local water officials before it is fully achieved.

Each local water authority is, with varying emphasis depending upon the particular local circumstances, expected to take definite steps and to apply

A paper presented on December 30, 1941, at the New York Section Meeting, New York City, by Anselmo F. Dappert, Prin. San. Engr., New York State Dept. of Health, Albany, N. Y. (See Editor's Note at end of paper.)

certain measures to: (1) protect water supplies; (2) reinforce or correct weaknesses in water supplies and distributing systems; (3) bring water supplies to the highest possible level of operating efficiency; (4) make specific plans for the handling of emergency situations; and (5) co-operate in a mutual aid arrangement whereby any community in distress may be supplied promptly with assistance from adjoining or neighboring communities.

For purposes of administration, the state has been divided into 23 zones. With the exception of New York City and Westchester, Nassau and Suffolk Counties, which constitute separate zones, the zones correspond to existing state health districts. In New York City, the Commissioner of the Department of Water Supply, Gas and Electricity has been appointed Zone Co-ordinator and the Deputy Commissioner and Sanitary Engineer of the Health Department as Assistant Co-ordinator. In the other zones outstanding local water officials or engineers have been appointed as zone co-ordinators, with the county sanitary engineers of the above-mentioned counties and the district engineers of the State Department of Health serving as assistant co-ordinators. The Assistant Director of the Division of Sanitation of the State Department of Health was appointed State Water Supply Co-ordinator.

It is the duty of zone co-ordinators with every means at their command to translate the various specific objectives of the plan into actual accomplishments. It is their job, too, to promote local co-operation, give assistance and direction to the work and otherwise serve as intermediaries between the State Co-ordinator and the local water authorities in carrying the plan into the fullest possible state of effective operation.

### **Preliminary Work**

The various specific objectives and the channels of activities which should be followed to attain them are easy to state, having been indicated rather clearly at a meeting of zone co-ordinators held in Albany on October 31, 1941, and subsequently through a series of memorandums which have been issued and will continue to be issued from time to time by the State Co-ordinator. Between the objectives of the plan and their actual accomplishment, however, lies a broad field beset with many difficulties, having manifold ramifications, and which can be solved only by the expenditure of much laborious effort on the part of the co-ordinators and by the fullest and most painstaking co-operation on the part of all local water authorities. The final and ultimate objectives of the plan may never be completely reached but a reasonable approach to these objectives should bring public water supply systems and local water authorities to such a state of pre-

paredness that emergency situations of all kinds and of any degree will be handled with the maximum of speed and efficiency.

The requisite initial steps have been to instruct zone co-ordinators fully in their duties and to acquaint local water authorities with, and enlist their co-operation in, the work. In several areas, such as New York City and Westchester and Nassau Counties, considerable progress toward the aims and objectives of the mutual aid plan had been made prior to adoption of the state-wide plan. In those cases, it has been fairly simple to adjust matters so that none of the work which has been done will be lost or sacrificed in any way.

To acquaint local officials with the plan, meetings of water officials have been held, or arranged for at an early date, in all zones; and, as the work progresses, additional meetings and conferences will be held from time to time and the work followed up, wherever necessary, through personal conferences with local water superintendents by the zone and assistant zone co-ordinators. Ultimately, the State Co-ordinator will expect to obtain information from the zone co-ordinators regarding conditions in each community and the specific action which has been taken in conformity with the aims and purposes of the plan.

#### Relation to Local Defense Organizations

Recognizing that the plan is an important defense measure and that the civilian defense program has been developed on the basis of having all defense activities geared to and co-ordinated through local defense councils, it is readily apparent that the work should be integrated with the work of defense councils and local health preparedness committees. Toward this end, conferences have been held between the State Co-ordinator and representatives of the State Defense Council and the State Health Preparedness Commission. Also zone co-ordinators have been instructed to confer with local defense councils and local health preparedness committees to the end that there will be complete harmony and co-operation among all interests. With respect to certain features of the plan, the assistance of local defense committees will be required. Complete understanding of the plan and its aims and purposes on the part of local water officials is essential for proper co-ordination of efforts. Steps have been taken to promote these mutual understandings; and, in general, the work under the plan has been satisfactorily integrated with the work of local defense organizations. Such problems as may present themselves should not be difficult to solve.

Essentially, the relationship between this plan and the work of local defense organizations should be one wherein the local water officials are

constituted as an integral part of the local defense organization but completely in charge of all water supply matters and volunteer workers who may be assigned to emergency water duties. Above the local level the relationship should be one wherein all matters related to the mutual aid plan are cleared by the local water authorities through the zone co-ordinators, with the State Co-ordinator responsible directly to the State Defense Council for satisfactory progress in connection with the work.

### Inter-Connection Program

The inter-connection program of the plan must be carefully distinguished from the program which has been in effect for a number of years and which has been accelerated recently to secure the elimination of dangerous cross-connections. Dangerous cross-connections should be eliminated and prevented. Inter-connections between public water supplies and *approved* supplies of industries or other *approved* supplies should be made to the fullest extent possible. This is one of the specific objectives of the plan and is being promoted in every way possible. Throughout the state there are already about 100 such inter-connections between adjoining municipalities, water companies and water districts. At least 200 more which are feasible will be made as soon as possible.

Reduced to a local point of view, it is expected that each local water authority will give serious consideration to the existing possibilities for inter-connection with an adjoining or neighboring municipal or public water system or for inter-connection with *approved* industrial or other *approved* systems. It is expected that each municipality will proceed at once with the installation of all such inter-connections which are feasible and which can be made at nominal expense, and that, at least, plans will be prepared for inter-connections which are too costly for immediate construction but which, nevertheless, are desirable and should be included in a long-range plan. In each instance, zone co-ordinators are instructed to co-operate with local officials in regard to the problems, to secure the preparation of plans, to submit preliminary sketches to the Board of Fire Underwriters or to the New York State Fire Insurance Rating Organization for suggestions and appraisal as to the value of such inter-connections from the fire protection standpoint, to obtain final plans for the State Co-ordinator and other state agencies which are concerned, and, otherwise, to give every assistance possible in securing installation of the inter-connections.

Up-to-date maps of distributing systems and adequate detailed records of valve locations are essential to any plan designed to meet emergencies. It is one of the purposes of the plan to have such records brought up to date in each municipality of the state. In a surprisingly large number of

communities, no adequate maps are available and all detailed information concerning the system is carried in the head of the local superintendent of water. Much effort is being expended now to have all the essential data concerning each system reduced to a permanent record available for quick reference in the event of emergencies.

### Co-operation With Local Fire Officials

Under the plan, local water authorities are being specifically requested and urged to co-operate closely with local fire officials in regard to matters of mutual interest. Certain co-operative studies and activities should be carried on in each municipality:

1. A detailed survey should be made of all possible sources of water supply which may be needed in a disastrous fire or acute emergency, and of all the equipment which will be needed for the utilization of such sources. Wherever possible, necessary equipment should be made ready for operation on short notice.

2. Fire officials should have full knowledge of the location and characteristics of all fire hydrants and valves and these hydrants and valves should be tested with sufficient frequency to assure proper operation. Where hydrant adapters are required, these should be provided.

3. A detailed study should be made of each distributing system, with particular reference to bottlenecks and weaknesses, and steps should be taken to correct these to the fullest possible extent.

Much activity on the part of local water and fire officials in the direction of these particular objectives is now under way.

### Additional Precautions

Local authorities are being urged to confer with representatives of power companies with a view toward ascertaining what situations will exist in event of power failures. Unless there is positive assurance that power can be maintained, water works which are dependent upon a single source of power should take steps immediately to provide auxiliary power equipment.

In cases where a defense industry is located in the municipality there should be a review of the adequacy of water service and fire protection furnished to such industry. This should be considered jointly by the representatives of the industry, the local fire officials and local water authorities.

In any serious demolition of water pipes, there will be an urgent need for experienced pipe layers, repair crews, etc. It is therefore, desirable, particularly in the larger communities, that steps be taken not only to train regular water department employees in emergency duties, but to organize and train reserve crews to fit in the water department organization

in case of an emergency. Volunteer workers assigned by local defense committees for such work should be given some advance training so that, in the event of emergency, they will know exactly what their duties are and be able to perform them with a minimum of supervision.

The idea of developing a detailed plan for handling various hypothetical emergency situations in each local water department is being encouraged in every way possible. In some communities such plans have already been worked out in great detail.

All local water authorities are being asked to consider their own systems thoroughly in the light of possibilities for sabotage, and to take such steps as seem to be indicated by the particular conditions. Actually, a great deal of progress has been made in this direction since the declaration of war. Because detailed information in this regard must be kept strictly confidential, no specific data can be presented. It can be said, however, that, on the whole, local water officials are fully alert to such possibilities and have taken appropriate action. This is a matter concerning which local water authorities have been considerably advised during the past two years.

### Inventory of Personnel and Equipment

One of the primary purposes of the Mutual Aid Plan is, as the name applies, to facilitate the extension of assistance by neighboring communities to communities in distress. To accomplish this, it is necessary that the resources and facilities of all communities be pooled in such a way that if the extreme need for personnel or equipment arises in any one community, the plan will operate to make it possible to supply the needs promptly.

Inventory forms have been supplied to all zone co-ordinators. These generally have been distributed to all local water authorities, and it is expected that they will be completed within a few weeks. The headings of these inventory forms are reproduced in reduced size on the following pages. These inventories will be held in confidence by each zone co-ordinator and he will be the clearing house through which emergency requests for needed personnel, equipment or supplies will be handled.

The Mutual Aid Plan has been in operation for only two months but much headway has already been made toward accomplishment of the various objectives. That much remains to be done is readily admitted, but certainly, in comparison with conditions of only a few months ago, the municipalities of the state are fairly well prepared. Co-operation on the part of all local officials has, as was expected, been excellent. It is this fact which gives encouragement to all who are concerned with administration of the plan and which will assure its success in the highest possible degree.

## INVENTORY SUMMARY

ZONE NO. _____	PERSONNEL				SHEET 1	
Municipality or Water Co., etc.	Experienced in Water Works Operation		Experienced in Pipe Laying-Repairs		Experienced in	
	No. Reg. Employees	No. Other Persons	No. Reg. Employees	No. Other Persons	No. Reg. Employees	No. Other Persons

ZONE _____ HYDRANTS, HYDRANT ADAPTERS, AND VALVES						SHEET 2
Municipality or Water Company	HYDRANTS		ADAPTERS		VALVES	
	Number	Sizes	Number	Sizes	Number	Sizes
	(all kinds)		(all kinds)		(all kinds)	

ZONE _____	PIPE				SHEET 3	
Municipality or Water Company	CAST		IRON	OTHER KINDS		
	Total Feet	Sizes	Total Feet	Kind	Sizes	
	(all sizes)		(all sizes)	(all sizes)		

ZONE _____	TEES.	CROSSES.	AND	BENDS _____	SHEET 4	
Municipality or Water Company	TEES		CROSSES		BENDS	
	Number	Sizes	Number	Sizes	Number	Sizes
	(all kinds)		(all kinds)		(all sizes)	

ZONE _____	SOLID SLEEVES.		SPLIT SLEEVES.		TAPPING & OTHER SLEEVES		SHEET 1
Municipality or Water Company	Solid Sleeves		Split Sleeves		Tapping or Other		
	Number	Sizes	Number	Sizes	Number	Sizes	
	(all sizes)		(all sizes)		(all sizes)		

ZONE _____	REDUCERS.	INCREASERS.	BRANCHES AND COUPLINGS		SHEET	
Municipality or Water Company	REDUCERS OR INCREASERS		C. I. BRANCHES		COUPLINGS	
	Number	Sizes	Number	Sizes	Number	Sizes
	(all sizes)		(all kinds)		(all kinds)	

ZONE _____	PLUGS	CAPS	AND	OFFSETS	SHEET 7	
Municipality or Water Company	PLUGS		CAPS	OFFSETS		
	Number	Sizes	Number	Sizes	Number	Sizes
	(all kinds)		(all kinds)		(all sizes)	

ZONE _____	PORTABLE PUMPS.	FIRE ENGINES.	PUMP PARTS _____	SHEET _____
Municipality or Water Company	PORTABLE PUMPS		FIRE ENGINES	PUMP PARTS
	Number	Capacities	Number	Capacities
	(all kinds)		(all kinds)	
				Notation of Kinds

### INVENTORY SUMMARY

ZONE _____	CHLORINATORS	CHLORINATOR SPARE PARTS			SHEET 8
Municipality or Water Company	Number	Type	Make	Capacity	Kinds of Spare Parts

Municipality or Water Company		MILK TRUCKS OR OTHER EQUIPMENT FOR HAULING WATER	
Number (all kinds)	Capacities	Number	Kinds of Trucks or Equipment
Municipality of _____		MILK TRUCKS OR OTHER EQUIPMENT FOR HAULING WATER	
Water Company _____		MILK TRUCKS OR OTHER EQUIPMENT FOR HAULING WATER	

Municipality or Water Company						COMPRESSORS		CRANES		TRACTORS	
						Number	Air Tools	Number	Capacities	Number	Kinds
ZONE _____						COMPRESSORS, CRANES, TRACTORS WITH POWER TAKE-OFFS _____ SHEET II					

ZONE		GASOLINE MOTORS,		ELECTRIC MOTORS, PULLEYS OR CHAIN HOISTS		SHEET 12	
Municipality or Water Company	GASOLINE MOTORS Number Horse Power	ELECTRIC MOTORS Number Horse Power	PULLEYS OR HOISTS Number Size or Kind				

ZONE	TAPPING MACHINES, WET CUT MACHINES, CUTTING MACHINES, SMALL SHEET IR TOOLS			
Municipality or Water Company	TAPPING MACHINES Number Remarks	WET CUT MACHINES Number Remarks	CUTTING MACHINES Number Remarks	SMALL TOOLS Listed on Inventory?

ZONE _____ FLOODLIGHTS, PIPE LOCATORS, LEAK DETECTORS, DIPPING BULL SHEET 14 NEEDLES, DOZERS.-				
Municipality or Water Company	FLOODLIGHTS	PIPE LOCATORS	LEAK DETECTORS	DIPPING BULL NEEDLES DOZERS
Listed in Inventory?	Listed in Inventory?	Listed in Inventory?	Listed in Inventory?	Listed in Inventory?

[illegible][illegible]

## INVENTORY SUMMARY

SHEET 9

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SHEET 10

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SHEET 11

SHEET 12

SHEET 13

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SHEET 14

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SHEET 15

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SHEET 16

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ZONE	ADDITIONAL SUPPLIES, EQUIPMENT OR MATERIALS	SHEET 17
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Municipality or Water Company	LIST	AND	BRIEF	DESCRIPTION
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Footnote: Total each column on each page

ZONE	LIST OF WATER SUPERINTENDENTS	SHEET 18
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Municipality or Water Company	Name of Sup't.	Address	Tel. No.
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ZONE	LIST OF WATER WORKS EXPERTS, CONSULTANTS, CHEMISTS, ETC., NOT LISTED AS WATER DEPARTMENT PERSONNEL	SHEET 19
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Name	Address	Tel. No.	Specialized in
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ZONE	LIST OF WATER LABORATORIES EQUIPPED FOR CHEMICAL OR BACTERIOLOGICAL EXAMINATIONS	SHEET 20
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Name of Laboratory	Address	Director	Equipped for Bac. Chem.
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ZONE	LIST OF CHLORINATORS AT CAMPS, HOTELS, SWIMMING POOLS, SEWAGE PLANTS, MILK PLANTS AND OTHER PLACES.	SHEET 21
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Name Establishment	Name, Address & Tel. No. of Person in Charge	CHLORINATION EQUIPMENT No. Type Make Capacity	Period of Year When not Used
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ZONE	DATA ON RESERVOIRS AND ELEVATED TANKS	SHEET 22
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Municipality or Water Company	Type of Storage or Equalizing Reservoir or Tank	Location	Capacity	Elevation	Source of Supply
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ZONE	DATA ON PUMPING STATIONS	SHEET 23
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Municipality or Water Company	Location Pump Station	Regular Operating Equipment	Standby Equipment
		No. Kind Cap. of Each	No. Kind Cap. of Each

ZONE	EXISTING INTERCONNECTIONS BETWEEN PUBLIC WATER SYSTEMS	SHEET 24
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Ref. No.	Municipality	Municipality	Size	Location
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## INVENTORY SUMMARY

POSSIBLE OR PROPOSED INTERCONNECTIONS BETWEEN PUBLIC WATER SYSTEMS					SHEET 25
Ref. No.	Municipality	Municipality	Size	Location	

Ref. No.	Municipality	Municipality	Size	Location	
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EXISTING INTERCONNECTIONS BETWEEN PUBLIC AND APPROVED INDUSTRIAL OR OTHER WATER SUPPLIES					SHEET 26
Ref. No.	Municipality	Other Approved Water Supply Owner	Source	Remarks	

Ref. No.	Municipality	Other Approved Water Supply Owner	Source	Remarks	
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POSSIBLE OR PROPOSED INTERCONNECTIONS BETWEEN PUBLIC AND APPROVED INDUSTRIAL OR OTHER WATER SUPPLIES					SHEET 27
Ref. No.	Municipality	Other Approved Water Supply Owner	Source	Remarks	

Ref. No.	Municipality	Other Approved Water Supply Owner	Source	Remarks	
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DISTRIBUTION SYSTEM MAPS				SHEET 28
Municipality or Water Company	Prepared	Progress Toward Preparation	Furnished to Zone Coordinator	

Municipality or Water Company	Prepared	Progress Toward Preparation	Furnished to Zone Coordinator	
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BOOK RECORDS - VALVE LOCATIONS, ETC.			SHEET 29
Municipality or Water Company	Complete Records Maintained	Progress Toward Records	

Municipality or Water Company	Complete Records Maintained	Progress Toward Records	
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LIST OF COMMUNITIES WHERE SURVEYS HAVE BEEN MADE OF POSSIBLE EMERGENCY SOURCES OF WATER SUPPLY IN COOPERATION WITH LOCAL FIRE OFFICIALS				SHEET 30
Municipality	POSSIBLE Number	EMERGENCY Number	SOURCES Plans Worked Out as To Methods of Utilization?	

Municipality	POSSIBLE Number	EMERGENCY Number	SOURCES Plans Worked Out as To Methods of Utilization?	
		Involving Pumping into Water System	Yes or No	Remarks

LIST OF MUNICIPALITIES WHICH REPORT COOPERATION WITH FIRE OFFICIALS IN REGARD TO CHARACTERISTICS AND TESTS OF VALVES AND HYDRANTS.				SHEET 31
Municipality	Reporting Conferences, etc., With Local Fire Officials in Regard To Mutual Problems	Reporting Progress or Completion of Valve Tests for Operating Cond.	Reporting Progress or Completion of Hydrant Tests for Operating Cond.	

Municipality	Reporting Conferences, etc., With Local Fire Officials in Regard To Mutual Problems	Reporting Progress or Completion of Valve Tests for Operating Cond.	Reporting Progress or Completion of Hydrant Tests for Operating Cond.	
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## INVENTORY SUMMARY

ZONE _____	LIST OF MUNICIPALITIES WHICH HAVE MADE STUDIES IN REGARD TO WEAKNESSES IN DISTRIBUTING SYSTEMS		SHEET 32
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Municipality	Study Made	Results, Action Taken, Remarks, Etc.	
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ZONE _____	LIST OF MUNICIPALITIES WHICH HAVE MADE COOPERATIVE STUDIES CONCERNING ADEQUACY OF WATER AND FIRE PROTECTION FURNISHED TO INDUSTRIES ENGAGED ON NATIONAL DEFENSE WORK.		SHEET 33
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Municipality	Study Made	Industry	Results, Action Taken, Remarks, Etc.	
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Zone _____	LIST OF MUNICIPALITIES WHICH HAVE MADE COOPERATIVE STUDIES WITH OTHER UTILITIES, POWER COMPANIES, ETC., IN REGARD TO MUTUAL PROBLEMS		SHEET 34
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Municipality	Study Made	Utility	Results, Action Taken, Remarks, etc.	
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ZONE _____	LIST OF MUNICIPALITIES WHICH HAVE ESTABLISHED SOME KIND OF TRAINING CLASSES OR INSTRUCTION PERIODS FOR REGULAR OR RESERVE EMPLOYEES		SHEET 35
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Municipality	Instruction, Etc., Carried on	No. Regular Employees	No. Reserve or Auxiliary Employees	Remarks
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ZONE _____	LIST OF MUNICIPALITIES WHICH HAVE GIVEN SERIOUS CONSIDERATION TO POSSIBLE SABOTAGE AND TAKEN SOME ACTION IN REFERENCE THERETO		SHEET 36
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Municipality	Studied or Seriously Considered	Action Taken, Remarks, Etc.	
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EDITOR'S NOTE: As of the middle of January 1942, we have information that the following states have established a Mutual Aid Plan in one form or another: California, Georgia, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, and Tennessee. It is evident that other states have such procedures in development. As plans develop, it is hoped that information will be filed with the A.W.W.A. headquarters office.



## Maintenance of Centrifugal Pumps

*By Vance C. Lischer*

THE response to duty of those charged with delivering an adequate and safe water supply to the public must necessarily include a sound policy and technique for the maintenance of all equipment, in addition to the customary provisions for standby. A poor maintenance program overworks standby equipment and will ultimately lead to trouble. A good maintenance program practically eliminates failures. This paper will be limited to a discussion of maintenance problems and methods involved in the care of centrifugal pumps. Prime movers and other types of pumps will not be included. Due to the fact that such considerations as organization, personnel and maintenance policies and facilities are so important to the successful solution of the problems encountered, a large portion of discussion will be devoted to these factors. The suggestions made are based on experience in the maintenance of the equipment of the St. Louis County Water Co. and on observations of maintenance procedures of other water works, as reported in the literature of the last ten years.

Regardless of the size of a plant, its maintenance policy must be determined by the potential hazard of failures. In the small system, if a high degree of standby is provided, allowing outages of a unit for several days or a week, the policy may be simply to replace damaged or worn parts. Obviously, only simple tools and relatively unskilled personnel are required in such cases. This policy will, of course, be more general in systems of less than 10 mgd. capacity, unless a consolidation of the repair shops of the water works and of other city departments is practical. Unless a complete set of spare parts is stocked, working agreements with local machine and welding shops are desirable in systems of such small size.

In larger plants a well equipped shop and a thoroughly trained personnel are necessary, since stocking an adequate supply of spare parts is

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A paper presented on October 22, 1941, at the Missouri Valley Section Meeting, Cedar Rapids, Iowa, by Vance C. Lischer, Engr. in Charge of Production, St. Louis County Water Co., St. Louis.

impractical. To permit equipment to lie idle while parts are being ordered is neglectful. The responsibility of furnishing an uninterrupted supply of water is so great that the cost of providing adequate shop facilities is a legitimate charge against the service. Such a shop should be equipped to make a great many of the replacement parts required and to restore worn or damaged parts to useful service.

### Shop Facilities

To make satisfactory repairs, considerable thought must be given to the selection of shop equipment and tools. A liberal policy in equipping the shop with proper tools of good quality will have a beneficial effect on the attitude and work of all employees. The more important equipment of a shop charged with maintaining centrifugal pumps should include:

1. Welding equipment—oxyacetylene and electric arc
2. Lathes—one capable of swinging the largest impeller assembly is indispensable and a smaller one will also be desirable, if the largest lathe swings 15 in. or more
3. Shaper or milling machine, or both
4. Drill press
5. Power hack-saw
6. Flame cutting equipment
7. Micrometers, calipers and gages
8. Portable electric tools—grinders and drills
9. Tool post grinder
10. Stationary grinders
11. Forcing press
12. Metal spraying equipment
13. Sand blasting equipment
14. Arbor press
15. Pneumatic tools, chippers, etc.
16. Coupling pullers

Supplementing these must be a well stocked store and tool room. The investment in a complete stock of machine and stove bolts and nuts, pipe fittings and other miscellaneous hardware will be found helpful in saving labor and time on emergency repairs. The tools in the tool room should be under capable supervision, should be stored on tool boards and should be checked out by means of a tag system. This insures their being available and in good condition at all times.

The physical shop equipment required is a separate problem for each plant and the selection of equipment and the establishment of policy should be determined after a careful analysis of the work to be undertaken.

### Personnel

The careful selection and training of the shop force is a very important responsibility of management. Each shop man should be capable of functioning well in a variety of skills as well as being a specialist in one or two. Thus, by diversifying the specialties, a force will be available for any eventuality. Some of the skills necessary for performing maintenance work on centrifugal pumps dependably are:

1. Machine shop ability on the lathe, the shaper and the milling machine
2. Welding ability by the oxyacetylene and electric arc methods
3. Flame cutting ability by hand and with the radiograph
4. Bearing repairing ability by babbitt scraping and pouring and by building up babbitt by spraying and welding
5. Grinding and polishing ability
6. Rigging ability
7. Painting ability
8. Pipe fitting ability on sweated, threaded, flanged and poured joints

Since the cost of a well equipped shop is a legitimate charge against service, just as is standby equipment, an excellent opportunity for training and giving experience to a larger than usual shop force is afforded, and the larger the force the more versatile and dependable it can be. Such increases in shop personnel can be made possible by diverting some of the money normally expended in the purchase of spare parts to labor costs for making these parts in the shop, wherever they can be made at a saving or at the same cost. The rehabilitation of worn parts formerly discarded will allow exceptional savings as well as providing excellent experience. The manufacturer is at a decided disadvantage in competing for such maintenance work, because, in his case, labor, material, profit, sales expense, which ordinarily is high, and overhead must all be charged against the product, whereas a water works shop will have only a limited amount of overhead in addition to labor and material. Taking advantage of this situation will help to maintain the skills of the shop force, as well as save money.

If local trade schools are available, a policy of encouraging employees to go to school by paying tuition and fees will reap advantages both in improved work and in employee relationships.

### Modern Maintenance Practice

The remarkable advances of the last two decades have revolutionized maintenance methods. Centrifugal pumps can now be made to last indefinitely by the use of modern methods. The outstanding difference between past and present practice is that in the past it was necessary to

discard much good equipment with the bad. Today, with modern welding and metal spraying methods, only the bad need be touched and little or nothing discarded. A part repaired by metal spraying or welding is generally as good as, and often better than, the original part.

Each maintenance problem should be carefully studied so that the solution which is most economical in the long run can be selected. Often the shop cannot compete with mass production as practiced in many industries. Therefore, cost figures should be kept on all functions performed by the shop, so that its work can be confined to that which is economically justified.

### Relation of Pump Construction to Economical Maintenance

Effective and economical maintenance requires that the machine to be maintained have design features that facilitate maintenance. Unfortunately the person charged with maintaining a machine often has no voice in its purchase. When a pump has defects it is often cheaper to correct them than to attempt to maintain the pump in its original form.

A case in point is the packing gland assembly. If the follower, lantern gland, and take-up bolts and nuts are of iron, resultant rust is certain to cause trouble. The follower will not be free, the take-up nuts will freeze on the bolts, the packing cannot be tightened with any assurance that the gland pressure will be proper, and the resultant improper gland pressure may cause excessive sleeve wear. The most effective remedy is to replace the iron parts with stainless steel or bronze. At the St. Louis County Water Co., fourteen cast-iron followers on seven identical 18-inch pumps were replaced with bronze at a total cost of \$98, including pattern cost, finishing and installation. The new followers were cast in a local foundry and finished in the plant shop. The original iron take-up bolts and nuts on the units had previously been replaced with brass. As a result of that experience company specifications for any new pump now call for a corrosion proof packing assembly.

Specifications should generally require renewable sleeves and wearing rings, though, if metal spraying is used as a regular maintenance procedure, they are not entirely necessary. It is desirable, too, to specify the use of high grade bronzes and brasses and, particularly, to avoid brasses of more than 15 per cent zinc—the so-called yellow brasses. When a pump is purchased, complete data concerning suction lift, total head and capacity should be given the manufacturer, so that a pump which will not be subject to cavitation can be selected.

The type of pump has a bearing on the cost of maintenance. Generally speaking, the split-case double-suction horizontal pump is the least costly to maintain. In the selection of the type of pump, factors affecting acces-

sibility, such as whether the motor or some of the piping must be moved to disassemble the pump, should be considered in evaluating the initial cost and in determining the selection. If the pump is to handle an abrasive or corrosive liquid, consideration should be given to the use of special and more costly materials because these will probably give the lowest long-run cost. Forethought in the selection of a pump may be the simplest solution to a troublesome maintenance problem.

Issued to: Shop Force Equipment: No. 3 Pump Location: Stratman Booster Station:	No. S58MSA3 Frequency: Semi-annually Charge Acct. 753-91
<b>Work to be done:</b> <ol style="list-style-type: none"> <li>1. Make general inspection of operation and condition of pump.</li> <li>2. Remove and clean packing followers.</li> <li>3. Clean and lubricate follower bolts and nuts.</li> <li>4. When replacing followers be sure packing is resilient and that the followers fit evenly. Repack if necessary.</li> <li>5. Check alignment of pump and motor</li> <li>6. Drain oil from bearings and add new oil</li> </ol>	

Date	Report	Signed	Date	Report	Signed

FIG. 1. Maintenance Record Card Used by the St. Louis County Water Co.; showing face (above) and a portion of reverse side (below)

### Maintenance Program and Records

To minimize failures of pumps while in operation and at times when they can least be spared, a periodic system of inspection and maintenance is necessary. The working schedule should not be left to memory but should be incorporated in a card system rotated in a calendar file. A simple maintenance card form, 8 by 5 in. in size (Fig. 1), used by the St. Louis County Water Co., has been highly successful.

When a maintenance card is issued to a shop man, the "Job Requisition" shown in Figs. 2A and 2B accompanies the card. The person to whom the work is issued records on this requisition all time and material as well as all data regarding the condition of the equipment and the work done. Extra sheets are available if needed. The maintenance card is filled out with the date, job requisition, and signature of the person doing the work, and

when the work is completed, the maintenance card is returned to the calendar file for its next regular turn. The job requisition is filed in an equipment file where, with other job requisitions and all pertinent data (for the same unit), a complete historical record is available.

The value of a routine scheduled maintenance program and a system of records is appreciated by conscientious workmen. It puts their work on record and creates in them the desire to do good work. By training and instructive criticism the average workman can be taught to record a useful account of the work he has done and the condition of the equipment. The value of such a system will be revealed many times. On numerous occasions, parts about to fail will be discovered. Factors which impair efficiency, but which do not affect operation, will be found where they might otherwise remain unnoticed. The plan will definitely reduce emergency repairs. The nature and frequency of inspections and work done should be varied, depending on the number of hours of operation, the character of the liquid being pumped and the experience gained in carrying out past maintenance work.

### Daily and Hour-to-Hour Inspections

The daily and hour-to-hour inspections and observations should be made by the operators on duty. It is felt that the use of the card system is unnecessary for these functions. The operators must, however, be impressed with the importance of their responsibility to detect and report irregularities in the operation of a pump. Bearing and packing temperatures should be observed hourly. Abrupt changes in temperature are of much more significance than high temperatures. Bearings can operate in continuous service at temperatures of 160°F. The "old-timer's" criterion of whether or not he could hold his hand on the bearing is of little value in terms of modern concepts. A thermometer should be used to determine temperatures if there is any doubt.

The operators should observe whether or not the oil rings in ring-lubricated bearings are turning and lifting oil. They should be sure that oil levels are at proper height. Changes in the sound of a running pump should be investigated immediately. The operators should account for all changes in pressure or flow in the pump discharge, as such changes are often an indication that something is wrong with the pump. If the packing is water-sealed and lubricated, it must be observed regularly to determine whether or not some water is dripping from the gland. The gland pressure should be checked occasionally to see that it is adequate. The lightest pressure that will maintain the seal is adequate. Generally this means that the nuts should be finger tight. The follower should always be square with the shaft. The best solution to most packing troubles is proper care during operation.

## JOB REQUISITION

No 5749

FILE UNDER No. 3 Stratman Pump  
 DATE March 1, 1941  
 ISSUED TO John J. Doe  
 ORDERED BY H.D.H.  
 AT REQUEST OF -----

CHARGE ACCOUNTS  
 LABOR 753-91  
 MATERIAL 753-91  
 EQUIPMENT TIME 753-91  
 TO BE COMPLETED By April 1, 1941

APPROVED BY Harry Smith ENGINEER

ORDERS Maintenance Card No. S58MSA3

## WORK DONE -- REMARKS -- CONDITION OF EQUIPMENT -- ETC.

*General condition of pump good.*

*Operation O.K. except outboard packing could not be drawn up to prevent excessive leakage.*

*Packing on that gland worn out. Repacked with graphited asbestos braided packing*

*Sleeve in good condition.*

*Alignment as found and left:*

*Pump 0.002 in. high*

*Pump 0.001 in. to west*

*Faces square*

ST. LOUIS COUNTY WATER CO  
 PRODUCTION DIVISION  
 FORM NO P 1

WORK COMPLETED March 15 1941

SIGNED John J. Doe

OVER

FIG. 2A. Face of Job Requisition Form Used by the St. Louis County Water Co.

JOB REQUISITION N° 5749

[illegible]

TOTAL LABOR COST

[illegible]

TOTAL MATERIAL COST

[illegible]

ITEM	COST
LABOR	
MATERIAL	
EQUIPMENT TIME	
TOTAL	

TOTAL EQUIPMENT COST

FIG. 2B. Reverse of Job Requisition Form Used by the St. Louis County Water Co.

The superintendent or his assistant should scrutinize all recording charts for changes that indicate trouble in a pump. The daily log sheet should have a column for recording a computed efficiency, kilowatt hours used per thousand gallons or pounds of steam used per thousand gallons.

### **Semi-Annual Maintenance and Inspection**

The semi-annual inspection should involve the use of maintenance cards and, preferably, should be done by someone other than the operator. In this inspection, the packing should be checked by the same procedure as outlined for the daily and hour-to-hour inspections. In addition, the follower should be removed and cleaned to be sure that nothing interferes with its free movement. The follower nuts and bolts should be cleaned and oiled. The gland should be repacked if there is evidence of improper functioning or if the follower is at the end of the take-up. Additional rings can be added if the balance of the packing is in good condition, but none should be added without first ascertaining that the lantern gland is centered under the sealing water inlet.

The alignment of the pump and driver should be checked, then corrected if necessary. Alignment should be kept within one or two thousandths of an inch, regardless of the type of coupling used. Oil lubricated bearings should be drained and refilled with fresh oil. Anti-friction bearings, i.e., ball or roller bearings using grease, should be checked to assure that the proper amount of lubricant is provided. Even on a continuously operating machine with anti-friction bearings, semi-annual lubrication checks are ample. Operators should not be permitted to add grease to these bearings unless they are properly trained to do the work. Generally more harm will result in over-greasing than in under-greasing where grease cups or pressure fittings are provided. Such devices often result in damage to the bearing seal and in excessive operating temperatures due to the fluid friction of excess grease. At the St. Louis County Water Co. plant, all grease cups and pressure fittings are removed and plugged. The operators are not permitted to lubricate anti-friction bearings.

### **Annual Maintenance and Inspection**

Annual maintenance and inspection should also be scheduled through the medium of maintenance cards and should be done by the shop force. All work done at the semi-annual inspection should be repeated and, in addition, other more thorough inspections and checks should be made.

The bearings should be removed, cleaned with a suitable cleaning fluid and carefully examined for flaws. The bearing housing should be flushed and cleaned. Anti-friction bearings should be completely cleaned of all old lubricants and examined for scratches and wear. The bearing should be given a light coat of grease if it is grease lubricated. When replaced

in the housing, if the bearing is on a horizontal shaft, grease should be added so that the bottom balls or rollers are about half-submerged. If the bearing is on a vertical shaft, the quantity added should be just enough to allow the balls to pick up the grease without plowing through an excess. The packing should then be removed and all parts of the assembly cleaned. The sleeves should be examined for wear as carefully as possible without further disassembling the pump.

The coupling should be disconnected and its alignment checked. With the pump in this condition and with the packing out, it should be rotated by hand to detect any rubbing or looseness. On horizontal pumps, with the packing out, the pump uncoupled and the bearings in place, the rotor should be raised with a bar at each end and the amount of vertical shaft movement measured with a dial indicator or feeler gage. If the vertical movement is greater than 0.010 in., the cause should be determined. In a sleeve or babbitt bearing, it may be due to looseness of the bearing in the housing. This can sometimes be corrected by examining the housing halves and removing any paint or burrs that may be preventing them from seating properly. A gasket should never be used on these surfaces unless the bearing was designed for one originally. If it is found that the play is in the bearing proper, then it may be necessary to repour or rebuild the babbitt.

With the packing removed and the coupling disconnected, the end play of the pump should be checked. If greater than that recommended by the manufacturer, it should be remedied. If the thrust bearing is babbitt, repouring or rebuilding as described later may be necessary. If it is an anti-friction bearing, complete replacement may be the only solution.

Drains should be cleaned and flushed. Drip pans and the drip catches under the glands should be cleaned and painted with a good water-resistant paint. Inspection of the external painted finish of the pump should be made and it should be repainted or touched up if required. It will probably be necessary to touch up bolts and nuts loosened during the inspection.

When the pump is repacked, it is permissible to re-use the removed packing provided it has not been damaged, is resilient and contains no foreign matter. If it is necessary to discard more than two rings of the removed packing in a gland, it will be desirable to replace all of the packing. The usable packing remaining from both glands, if the pump has two, can be used to repack one gland while new packing is used in the other. Service conditions will determine packing practices, the type of packing used and its reasonable expected life. The procedure suggested here for the annual inspection of gland assemblies, however, should not be avoided because it may increase packing costs. Much serious trouble and expense may be avoided by making this annual inspection.

If at all practicable, an efficiency and delivery test of the pump should

be included in the annual check-up. This should be taken care of by the use of a maintenance card issued to some member of the engineering staff or to the superintendent himself. Power input, total head, suction lift, speed and delivery are some of the items to be measured. A comparison should then be made with previous tests and with the manufacturer's characteristic curve to determine any course of action to be taken.

### Complete Overhaul

Periodically every pump should be completely disassembled and overhauled. A maintenance card should be used to insure that this work is done according to a predetermined schedule. The frequency of the operation will depend entirely on the average operating time of the unit, the type of water or liquid it is handling, the type of pump, its materials of construction, the importance of the unit and the maintenance technique. This schedule can easily be determined after several years experience. In general, for pumps handling finished water, a three- to five-year frequency is satisfactory. It would not be good practice to extend the frequency beyond five years because of the reassurance and confidence this inspection gives management.

If the pump is handling silt-laden abrasive raw water, annual overhauling may be required, particularly because of the increase in ring clearance and the consequent loss in efficiency. The intake pumps of the St. Louis County Water Co., handling raw Missouri River water, are overhauled annually because ring clearance in that time increases from 0.015 to 0.060 in. in diameter. The chemical pumps at the same plant are given a semi-annual internal inspection. The clear water pumps are overhauled every five years.

To facilitate the overhauling and to provide more complete stand-by it is often desirable to have a spare rotor, consisting of the shaft, impeller, wearing rings, and sleeves. Thus the time required to overhaul a pump can be materially reduced. The repair work on the spare rotor can be done at a later date when it is convenient.

### Casing Maintenance

In the interest of maintaining high efficiency it is desirable to keep the pump casing and its water passages smooth and free from rust tubercles. A new pump may have many casing irregularities unless the specifications called for a finished interior. During the first overhaul, the interior should be made smooth with power wire brushes and grinding wheels. After the surface has been thoroughly cleaned, it should be given no less than four coats of a good underwater paint. A paint of the phenol-formaldehyde type with aluminum powder has been found to give fair protection for

three to five years at the St. Louis County Water Co. Care should be taken not to put more than one coat of paint on the casing ring seats. The bonnet flanges should not be painted because the gasket may thereby be caused to stick. Figure 3 shows a pump bonnet after finishing and painting.

The spraying of zinc or aluminum on the interior surfaces of the casing is suggested as a better means of maintaining smooth corrosion-proof internal surfaces. The writer has had no experience with such practice, but it has been applied successfully to the interiors of large needle valves in hydroelectric works.

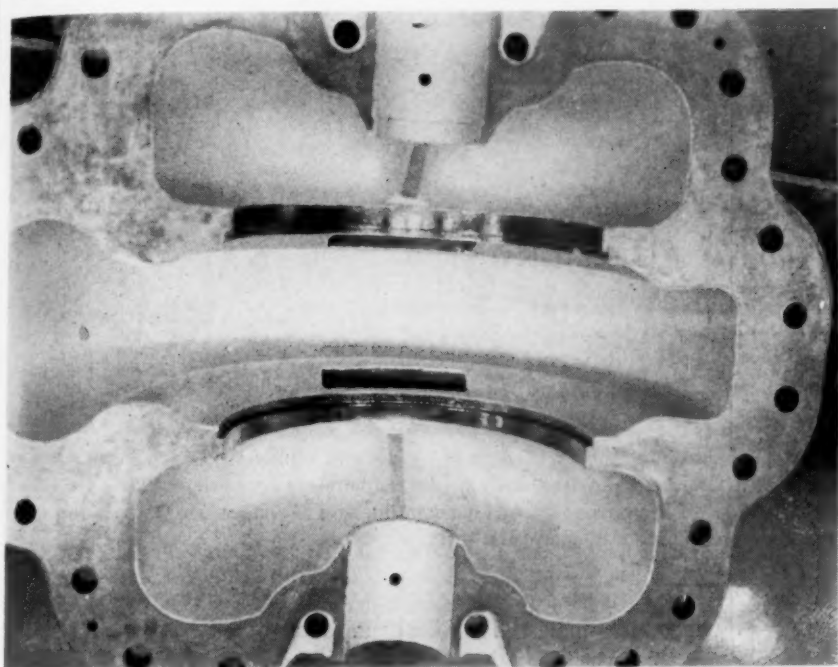


FIG. 3. Bonnet of 18-Inch Pump; after surface finishing and painting

If the casing is worn or pitted in places, these portions should be restored by welding or metal spraying. At the St. Louis County Water Co. a 16-inch double suction intake pump casing, which was damaged by sand wear to the extent that complete replacement was imminent, was restored to the usefulness of a new casing by bronze welding, at a cost of \$170. This work was done in 1933, at which time it was expedient to remove the unit to a local shop where the entire casting could be preheated while the welding was done. Today the job would be done by the maintenance force and it would not be necessary to remove the casing from its setting.

### Sleeve Maintenance

A badly grooved sleeve should not be put back into service. If the grooving is only minor, i.e., not more than  $\frac{1}{32}$  in. deep, the packing wearing surface can be refinished under size. If this is done, care should be taken that the clearance at the base of the stuffing box is not so great that packing is forced through into the pump interior. To remedy this, a brass ring about  $\frac{3}{16}$  in. thick and having not more than  $\frac{1}{32}$  in. clearance with the shaft can be inserted in the base of the stuffing box. This same expedient can be used in any stuffing box where the packing may be forced into the pump interior.

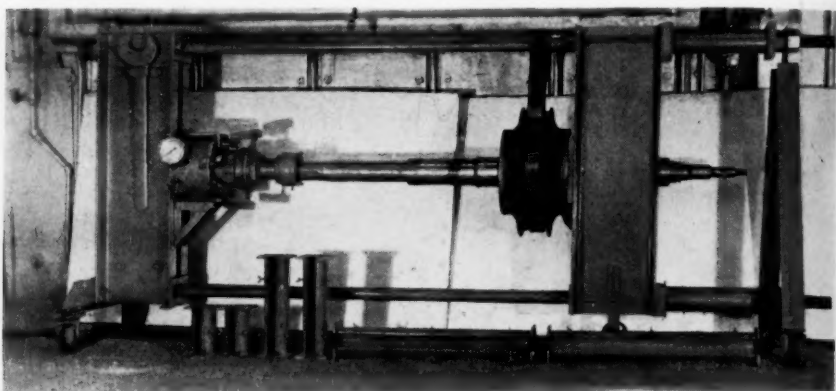


Fig. 4. Rotor Assembly, set up in forcing press preparatory to removing sleeves and impeller; press, constructed in shop of St. Louis County Water Co., uses 75-ton portable hydraulic jack with 9-inch stroke; on floor are spacers used ahead of nuts on right ends of draw rods; by various combination of spacers any length up to 84 in. can be accommodated in press.

If the grooving is excessive, repair or replacement of the sleeve is necessary. The procedure to be followed will be determined by the cost of a new sleeve and the cost of repairing the old. Experience at the St. Louis County Water Co. indicates that it is generally less costly to restore the old sleeve by bronze welding in the plant shop. Figures 4, 5 and 6 show various steps in the progress of this work on the sleeves of a 20-inch double suction pump. Unless the sleeve is worn very deep, it should be undercut in a lathe  $\frac{3}{32}$  to  $\frac{1}{8}$  in. before applying the overlay. Manganese bronze is applied with an oxyacetylene torch, as shown in Fig. 6.

After the welding is completed, the rotor parts are re-assembled and the work put in the lathe for refinishing. It will be found impossible to assemble purchased parts on an old shaft and have all finished surfaces concentric with the axis of the shaft. This applies especially to the ring and

sleeve surfaces. By finishing sleeve and wearing ring surfaces in the lathe with the rotor completely assembled, a perfect job in this respect is assured. It is particularly advantageous to follow this procedure on sleeve surfaces because eccentricity is one of the most frequent causes of packing trouble and the most difficult to be remedied. It is desirable to finish the sleeve by polishing as this reduces wear and friction.

For maintenance of sleeves, metal spraying is particularly advantageous and economical, since it is unnecessary to remove the parts from the shaft. The rotor is set up in the lathe, the surfaces to be built up are undercut and roughened, sprayed metal is applied, and the surfaces are refinished

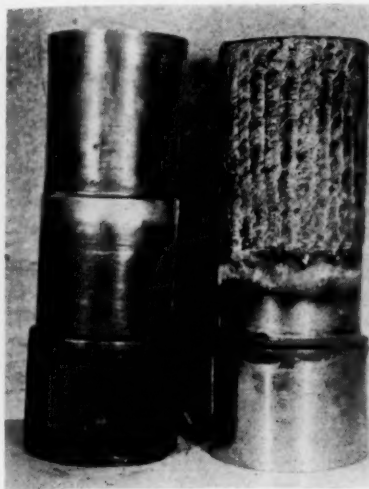


FIG. 5

FIG. 5. Shaft Sleeves, before and after Bronze Welding



FIG. 6

FIG. 6. Pump Sleeve, Being Built up by Welding; work done in front of boiler door to allow draft to carry away brazing fumes; welder wearing aspirator supplied through hose on floor at left

without removing the rotor from the lathe. The amount of machining is minimized because sprayed metal can be applied to not more than 0.030 in. over size. Metal spraying offers an added advantage in that hard alloys, which will give better performance than the original metal, can be used, whereas the welding process is largely limited to bronze because of the distortion resulting from building up by fusion welding. It is entirely possible to complete a sleeve maintenance job by the use of metal spraying, without removing the rotor from the pump. After spraying, the work can be machined or ground in place.

At the St. Louis County Water Co., in the maintenance of some chemical pumps handling abrasive and corrosive materials, the packing wearing sur-

faces are coated with "Stellite," a nonferrous hard surfacing material applied by the oxyacetylene flame. This process is quite costly because of the initial cost of the material and particularly because the finishing must be done by grinding. The resultant job, however, will outlast most materials several times. The shaft in Fig. 7 which does not have renewable sleeves was resurfaced near the impeller by this method at a cost of \$12. A new shaft of special alloy costs \$22.



FIG. 7. Chemical Pump Parts After Refinishing; portion of shaft near impeller hand-surfaced and ground to prevent packing wear; faces of impeller and casing machined to remove grooving and to make them true

Figure 7 also shows impeller and casing wearing surfaces of this pump after they had been refinished in a lathe. The flange on the pump head was undercut to allow the pump to be re-assembled with proper clearance. Re-assembling involved using shims and gaskets at various places to allow assembling with about 0.010 in. clearance on the front and back side of the impeller. The reduction in thickness of the impeller as a result of refinning causes some reduction in the capacity of the unit, which for the application is tolerable. At a later date the impeller edges will be built up or a new impeller installed to restore the unit to its original capacity.

If considerable abrasive material is present in the water being pumped, as is often the case with raw water pumps, clear water should be used on the seal. If clear water is not available, a waterproof grease seal may be used or any one of a number of plastic packings which require no sealing fluid.

### Wearing Ring Maintenance

Wearing ring maintenance is desirable whenever the clearance exceeds 0.015 to 0.025 in. in diameter. Excessive ring clearance reduces efficiency. For wearing ring repairs, as for the sleeve repairs, the cost of new parts as opposed to resurfacing by welding or metal spraying, should be the deciding factor. The procedure followed by the St. Louis County Water Co. is to resurface with bronze welding. Figure 8 shows a rebuilt impeller ring, preparatory to refinishing, and its companion casing ring.

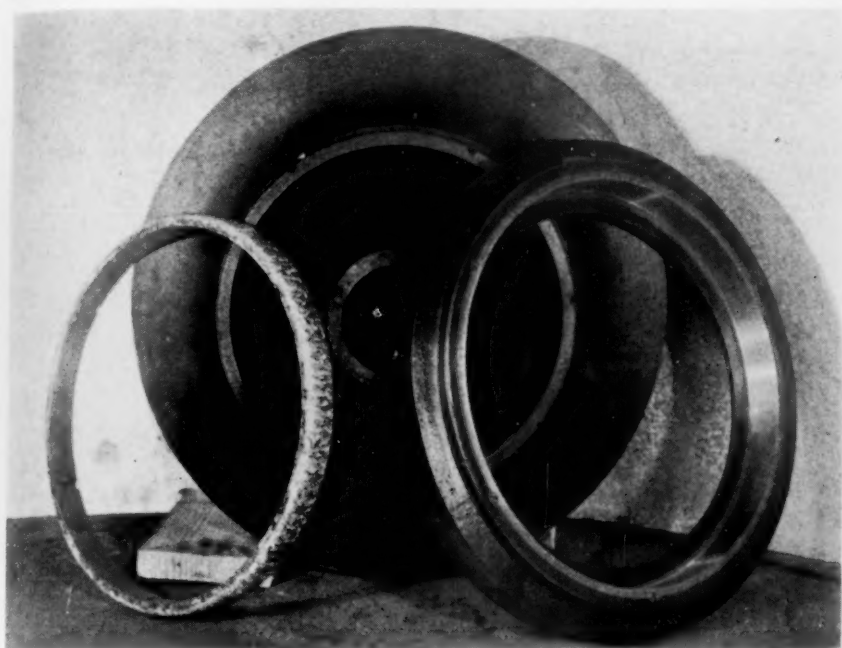


FIG. 8. 20-Inch Pump Impeller; refinished casing ring at right and bronze built-up impeller ring at left

To make such a repair only one ring need be rebuilt. The other is machined to a smooth surface and the built-up companion ring machined to fit. By alternately rebuilding one and then the other, the same rings can be made to last indefinitely. Impeller rings should be machined assembled on the impeller and shaft. The fit should be 0.010 to 0.015 in. depending on the condition of the bearings and casing. When the rotor is assembled in the pump, faulty bearings or a poor fit of the casing rings in the casing may cause the rings to rub. If there is rubbing, these items should be checked before the clearance is increased. A close fit means

higher efficiency. This procedure is for flat surface rings; labyrinth rings and other types will require a modified technique.

The complete ring and sleeve repair on the 20-inch pump rotor as illustrated "before and after" in Fig. 9 cost \$75.

A remedy resorted to in some instances where excessive abrasion is encountered, as is unavoidable in raw water pumps handling highly turbid

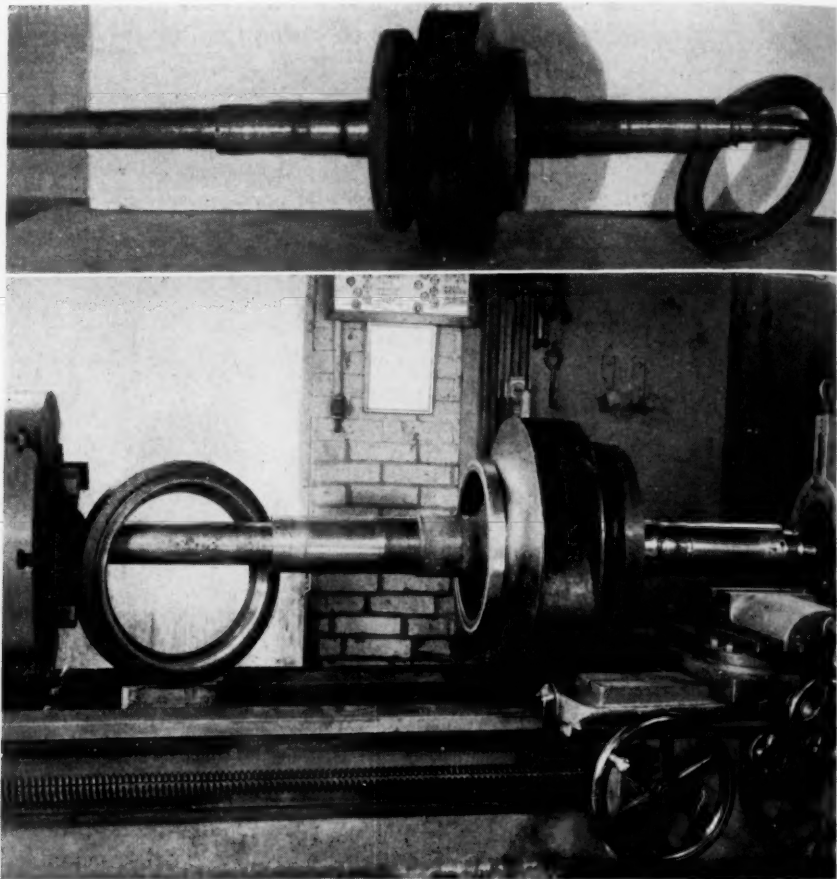


FIG. 9. 20-Inch Pump Rotor; before (above) and after (below) restoring sleeve and wearing ring surfaces

water, is to use clear water for flushing the rings. This is done by machining an annular groove in the center of the rings to act as a water passage, tapping this groove in several places from the outside of the casing, and connecting the taps to a clear water supply. The pressure in the annular space must be maintained higher than the pump discharge pressure and

must be applied at all times during the operation of the pump. In this way the gritty water being pumped will be prevented from entering the space between the rings by the outflowing clear water.

### Shaft Maintenance

The shaft should be straight, its bearing surfaces smooth, and the impeller and sleeves should fit tightly. The machined surfaces of the rings, sleeves and bearings should be concentric with the axis of the shaft to within 0.001 to 0.002 in.

A frequent cause of poor fit of impeller and sleeves is rusting and pitting of the shaft, resulting from water entering the joints between the impeller and the sleeves. In assembling the rotor, the end surfaces must be true and a plastic non-hardening filler should be used in the joints. Figure 10 shows a shaft where pitting and rusting have progressed to the point where a tight fit is no longer possible.

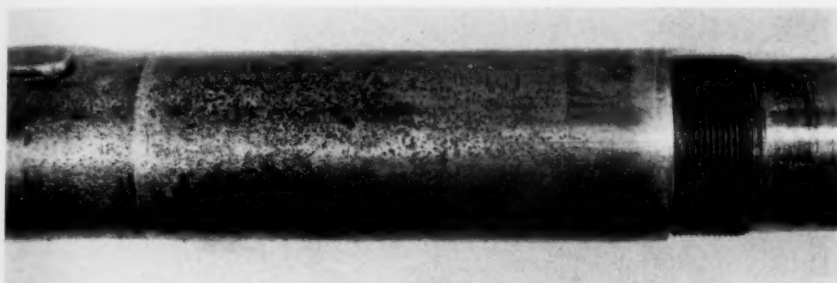


FIG. 10. Portion of 4-Inch Diameter Shaft of 20-Inch Pump; showing rusting and pitting caused by water leakage through joints between impeller and sleeves

Due to the distortion that would result if the original size were restored by adding metal by brazing or welding, such a procedure is not possible. By the use of metal spraying, however, the shaft can be restored to size at reasonable cost. By spraying with stainless steel, the shaft can be made better than its original form, as no subsequent pitting will take place. Metal spraying can also be used to restore a grooved bearing surface on a shaft. It is entirely possible to add sprayed metal and to finish the surface in place without removing the shaft from the pump. In like manner the fit of a coupling on a shaft can be restored by metal spraying.

### Bearing Maintenance

If an anti-friction bearing becomes damaged, it must be either reground or replaced. The regrounding must be done by the bearing manufacturer or someone similarly equipped to do the work. Regrinding generally

costs from one-half to two-thirds the cost of a new bearing. There are some who feel that the practice is not advisable because, in their opinion, the reground bearing is not as good as a new one. At the St. Louis County Water Co., however, a reground bearing the repair cost of which is about half the cost of a new bearing, allowing a saving of about \$45, is giving excellent service. Incidentally, it may be pointed out here that it is desirable to carry spare bearings for all important pumps provided with the anti-friction type of bearing.

When the clearance of babbitt bearings is in excess of 0.005 to 0.010 in., depending on the diameter of the shaft, corrective measures should be

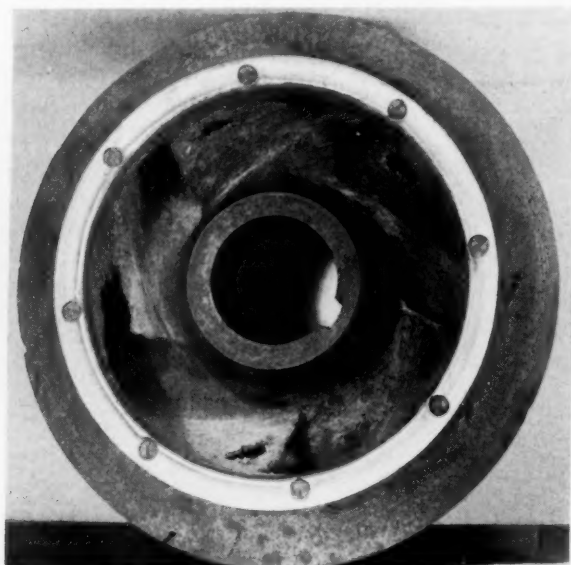


FIG. 11. Impeller of 12-Inch Raw Water Pump; showing effect of cavitation and abrasion

taken. It is good practice to repour the bearing using an undersize shaft and to restore it to size by machining in a lathe. This procedure minimizes the amount of scraping and insures a close fit. Surface imperfections which result when the babbitt is poured directly against the shaft generally result in a loose fit by the time the bearing is properly seated. Babbitt surfaces can be built successfully by the use of an oxyacetylene torch. This procedure is especially advantageous for repairing local defects. On small bearings it is sometimes faster than repouring the entire bearing. Babbitt can also be metal sprayed. This technique probably represents the most practical and economical means of restoring bearing surfaces.

### Impeller Maintenance

Abrasion, corrosion, or cavitation may call for impeller maintenance. In fresh water service, abrasion and corrosion will be at a minimum and an impeller can be expected to give fifteen to twenty years' life unless it is subject to cavitation. In raw water service, abrasion may necessitate periodic maintenance. Cavitation, wherever it exists, requires periodic inspection and replacement of lost metal. Figure 11 shows an impeller that was in use in raw water service where cavitation and abrasion rendered it economically beyond repair. Periodic maintenance could have given this impeller an indefinite life.

Figure 12 shows the results of cavitation on a cast-iron mix-flow impeller and the same impeller repaired by the use of stainless steel applied by

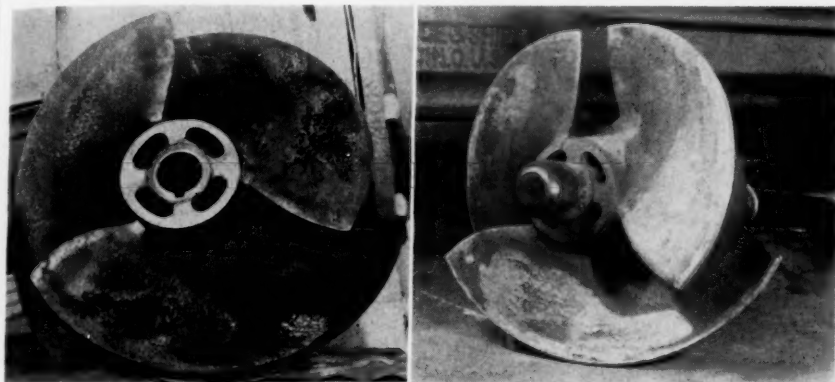


FIG. 12. 24-Inch Mix-Flow Impeller; showing (left) effect of cavitation, and (right) repairs and restoration to original diameter

oxyacetylene welding; Fig. 13 shows how the original diameter was restored by finish grinding the blade edges after they had been built up with stainless steel. Work such as this can generally be done at much less than the cost of a new impeller. Metal spraying has also been used successfully in the restoration of metal lost due to wear and cavitation.

Cavitation is caused by defects in the design or application of a pump. The only remedy is correction of the conditions causing it or periodic restoration of lost metal. The frequency of this periodic replacement of metal should be determined by the number of hours the unit operates and by the severity of the cavitation. Stainless steel, finished to a polished surface, has been found to give better protection than most other metals wherever cavitation is encountered.

An example of how special alloy castings can solve a maintenance problem at extremely low cost is illustrated by the method followed by the St.

Louis County Water Co. in maintaining five identical small-size  $\frac{1}{2}$ -hp. open impeller pumps handling lime slurry and ferrous sulfate solution. These pumps, which are subject to abrasion, are of inexpensive all-iron construction. They were being maintained, by the use of "Stellite" on surfaces subject to abrasion, at an annual cost which represented a saving over an initial installation of abrasion resistant pumps. The application of "Stellite" to the thin edges of the impeller blades resulted in a weakening of the cast-iron blades so that eventually they failed. Special alloy hard castings were obtained from a local foundry, using a new cast-iron impeller as a pattern. Alterations to the cast-iron impeller cost \$5.50 to make it suit-

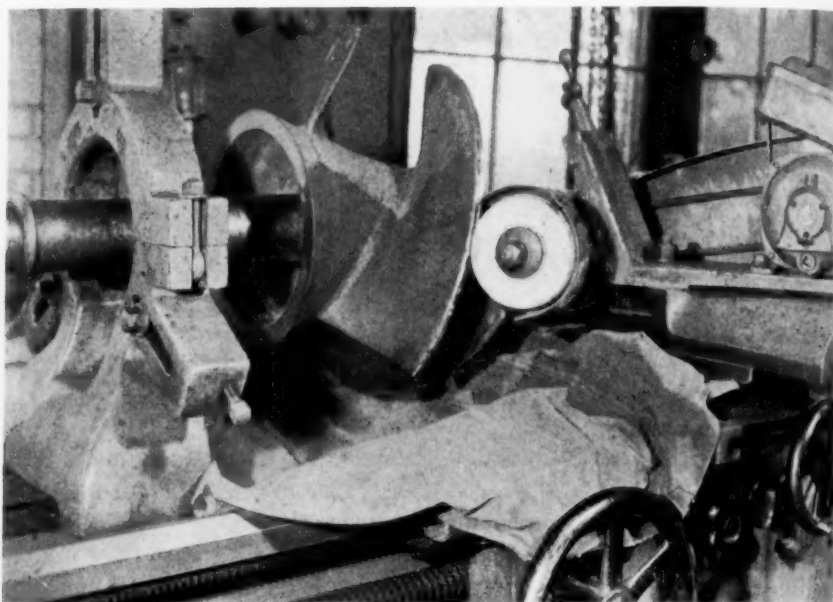


FIG. 13. 24-Inch Mix-Flow Impeller; showing finish grinding of outside edges after building up with stainless steel

able for a pattern. Six impellers were cast of high chrome alloy steel which was subsequently heat treated to produce a hardness of over 600 Brinell. Before heat treating, the impellers were machined, bored and key-seated in the plant shop. The unit cost of making these abrasion resistant impellers was slightly less than the \$7.50 the manufacturer charged for a cast-iron impeller.

Changes in maintenance technique will take place in the future just as they have in the past. Water works men should keep informed of the progress being made and adopt methods applicable to their problems.



## Ridding the Distribution System of Pumping Station Noises

By S. M. Dunn

**H**APPILY, consumer complaints regarding house piping noises which may be attributed to pumping station equipment are not frequent and, on the rare occasions when such complaints are received, the problems presented are seldom difficult to solve. Usually, when conditions arise in pumping stations which might cause noises in service piping, they are detected in the station before complaints are received from consumers; and, ordinarily, the noises produced are more objectionable because of their persistence than because of their intensity. Such noises as do occur are by no means comparable to the noises originating in plumbing fixtures and service meters, but these latter seem to be accepted by the consumer as irremediable, along with the other annoying, but inescapable, facts of nature.

Noises attributable to pumping station operation are usually classifiable according to their cause as due to pulsating flow, mechanical vibration, or shocks incident to cessation of flow. Pumping equipment of the reciprocating type ordinarily gives rise only to noises of the first of these classes, but equipment of the centrifugal type may be involved in all three categories.

Noises arising in pumping equipment of the reciprocating type are most often caused by faulty valve action, lack of sufficient air volume in air chambers, or excessive speed, and can usually be eliminated by limiting valve travel to the proper amount by installing valve springs with sufficient stiffness, by providing adequate air chamber volume or by decreasing speed, as the case requires. In some instances reciprocating pumps installed on consumers' premises, for delivering water from low pressure service mains to elevated tanks, cause noises which are transmitted back to the mains through the supply connections and then to the premises of other consumers. These noises can be eliminated by air chambers con-

A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., by S. M. Dunn, Chief Meeh. Engr., Bureau of Water Works and Supply, Los Angeles.

nected to the supply lines adjacent to the pumps, as such chambers tend to steady the flow and absorb the shocks caused by the closure of the suction valves.

In some instances improperly anchored piping on consumers' premises has been known to beat in unison with reciprocating pumps when the natural frequency of vibration of some piece of pipe happened to be a harmonic of the speed of operation of the pump, even though all other conditions for the elimination of noise had been satisfied. In such instances proper anchorage of the offending pieces of pipe has been necessary to correct the trouble.

### Noises From Centrifugal Equipment

Noises arising from the operation of centrifugal pumping equipment are usually due to one or more of five conditions: obstructed impeller ports, broken impeller shrouds, mechanical vibration, cavitation, and slamming of check valves on stopping. In searching for the sources of noises of the first two kinds, the casing of the offending pump is opened and the impeller examined carefully for rocks, blocks of wood and objects of a similar nature which may have become lodged in one or more of the passageways, and for missing shroud walls. The occurrence of noises due to stopped impeller ports has been relatively frequent, particularly when new plants are placed in operation. Broken impeller shrouds cause noises of the same character as stopped ports, but only occasionally are conditions of this kind encountered. Loose piping on consumers' premises may magnify noises of this character.

Noises due to mechanical vibration are sometimes difficult to eliminate. The vibration may arise in either the motor, the pump or the shaft coupling, and can be eliminated only by careful balancing. Vibration arising in shaft couplings is usually caused by worn parts. Couplings of the pin and rubber bumper type are among the worst offenders. Troubles of this nature most frequently arise with equipment operating at two-pole speed and may cause complaints from only one consumer on a whole system who happens to have some object in his home which vibrates at the same frequency as the speed of rotation.

In an interesting case of this kind, the glass in a small picture on a wall in a consumer's house emitted a peculiar ticking noise whenever a particular pump in the plant supplying the district was in operation, although the house in question was located approximately a quarter of a mile from the plant. This was, apparently, the only object in the system affected and, as the plant was new and had just been placed in operation, the consumer immediately suspected the new plant. The trouble was further aggravated by the fact that the complaining consumer was a prominent motion

picture actress. The pump was of the bracket-mounted type operating at 3,500 rpm., and it was necessary to replace the complete rotating element before the trouble was eliminated. The butler transmitted the complaint and carried on all negotiations.

Cavitation noises seldom occur except on equipment taking water under suction lift and, if the lift is not too great for satisfactory operation, are usually caused by too small a suction pipe or by partial stoppage of the suction strainer or suction pipe. It is not believed, however, that cavitation noises are transmitted to any distance on discharge mains.

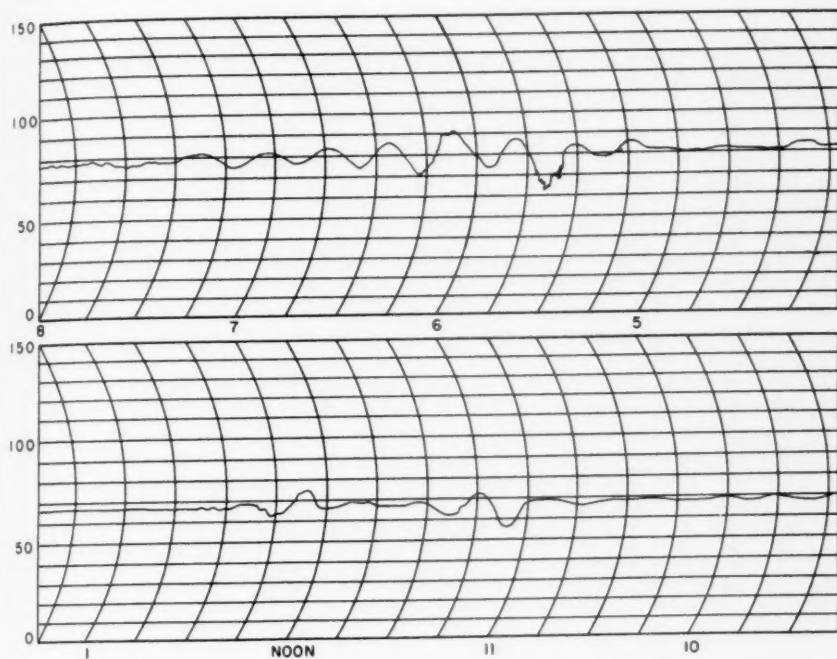


Fig. 1. Pressure Charts taken 1,200 ft. from plant in Hydro-Pneumatic System; stoppage of flow, 200 gpm., through 3-inch check valve; spindle torque—upper chart, none; lower chart, 120 in.-lb.

Swing check valves installed on the discharge nozzles of centrifugal pumps sometimes give rise to severe slamming noises in closing when the pumps are stopped by opening the starting contactors, as is the usual practice in small and medium capacity automatic plants, and it is often rather difficult to eliminate trouble of this kind in a satisfactory manner. The occurrence or non-occurrence of this phenomenon is dependent on the nature of the system into which the pump discharges, severe slamming being apt to occur when a pump discharges into a system in which the

line pressure does not decrease greatly when the pump is stopped, such as a system containing an elevated tank or hydro-pneumatic tank adjacent to the point of connection of the pump discharge. The pressure charts shown in Fig. 1 were taken on such a system at a distance of approximately 1,200 ft. from the pumping plant at the time of stopping of a pump discharging 200 gpm. into a hydro-pneumatic tank to which the discharge main is independently connected. These charts show that a severe shock is transmitted through the tank and along the main following the closing

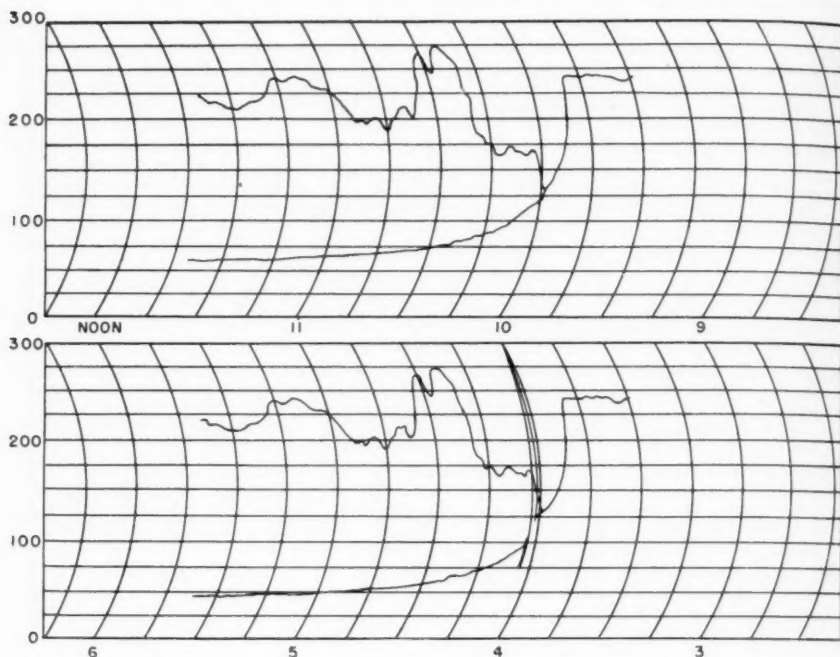
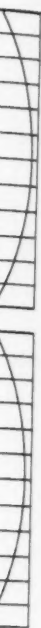


FIG. 2. Combined Inlet and Outlet Pressure Charts; stoppage of flow, 1,100 gpm., through 8-inch long-body check valve; spindle torque—upper chart, 310 in.-lb.; lower chart, none

of the check valve. Air chambers, placed on discharge lines near check valves for the purpose of decreasing line pressure surges, will also cause severe slamming. On the other hand, this trouble seldom occurs on lines subject to severe pressure surges when pumping equipment is stopped.

The sudden closure of the check valves in these troublesome installations is caused by the reversal of the direction of slope of the hydraulic gradient through the check valve, with consequent tendency for the direction of flow to reverse as the speed of the pump decreases in stopping. Naturally, this tendency for the flow to reverse is most pronounced in installations in

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which the pump discharge pressure tends to fall most rapidly with relation to the line pressure, which is the case in systems in which the line pressure does not decrease to any great extent when the pump ceases to discharge. The reversal of slope of the hydraulic gradient through a pump check valve as the pump speed decreases is quite evident in the upper of the two pressure charts shown in Fig. 2. These charts were made by combining charts taken simultaneously by two pressure recorders connected to the inlet and outlet ends of a standard swing check valve. It will be noted that the pressure at the inlet end has fallen several pounds below the pressure at the outlet end at the instant of closing.

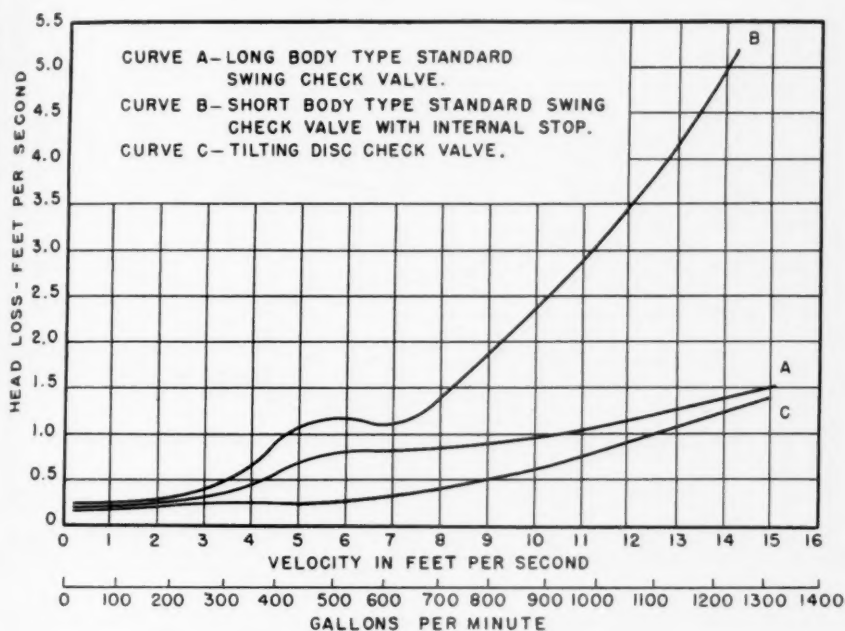


FIG. 3. Head Loss Through 6-Inch Long-Body, Short-Body and Tilting-Disc Type Check Valves; showing positions of disc in degrees of arc

Trouble of this nature can be eliminated by replacing the common swing check valve with a valve of the non-slam type (of which there are several on the market) or with an automatically controlled, hydraulically operated gate valve or plug valve. Among valves of the non-slam type, modified swing check valves of various kinds and various spring- or weight-actuated needle valves may be mentioned. Modifications of swing check valves include valves equipped with internal stops to prevent the discs from opening to too great an angle, valves equipped with tilting discs, and valves

with extended hinge spindles equipped with external weight- or spring-actuated levers. In considering the installation of such valves the question of head loss naturally becomes a matter of moment, and the following remarks on this subject may not be out of order.

Tests have been made on a number of valves of several types and sizes to determine the relation between head loss and velocity of flow. The results of these tests for several types of 6-inch valves are shown in Figs. 3-5.

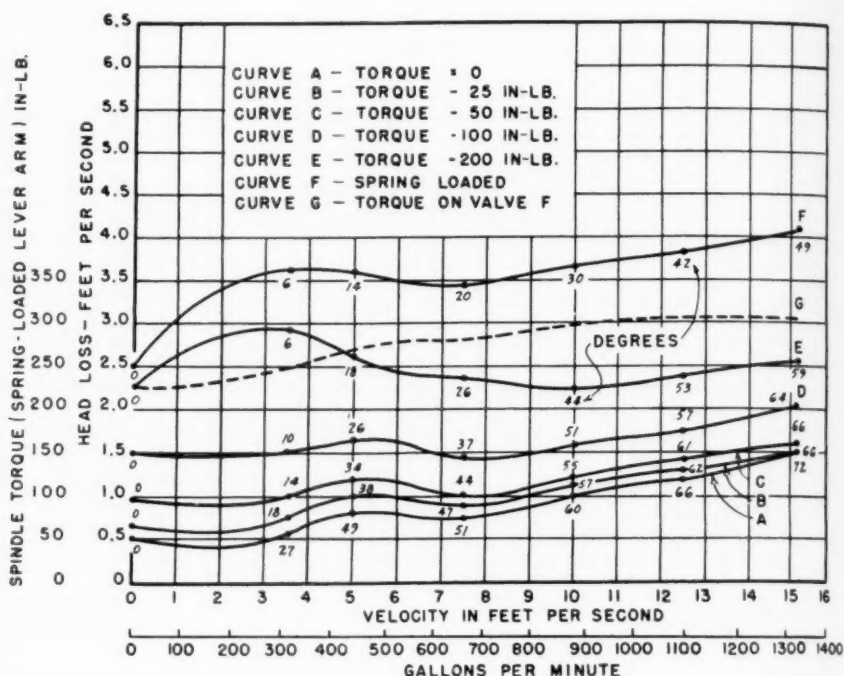


FIG. 4. Head Loss Through 6-Inch Long-Body Check Valve, with various amounts and types of closing torque

Referring to Fig. 3, Curve A shows the head loss through a valve of the long body type in which the disc is free to swing through an arc of approximately 90 degrees with no restraint other than the weight of the internal moving parts. This curve is inserted merely as a basis of comparison. Such valves slam in a very realistic manner when exposed to sudden reversals of flow and have been known to give rise to damaging pressure surges when the parts become worn. These valves, however, operate very satisfactorily in most installations if the attachment of the disc to the hinge member is designed for continuous use, which is not the case with prac-

tically all makes of valves of this type. It will be noted that the loss through this type of valve is not serious at velocities as high as 15 fps.

Curve B shows the head loss through a valve of the short body type with an internal stop which restricts the swing of the disc to not more than 45 degrees. Owing to this restriction the time required for the disc to swing to the closed position is relatively short, with consequent reduction in the tendency to slam, but the head loss at velocities in excess of 7 fps. is seen to be inordinately high when compared with the loss through Valve A. Consequently, if valves of this type are used it is often advisable to install an increaser between the discharge nozzle of the pump and the check valve to reduce the velocity through the valve.

Curve C shows the loss through a valve of the tilting disc type which, in this particular size, is somewhat lower than for the valve shown by Curve A. This relation is reversed for some sizes, however, the reason probably

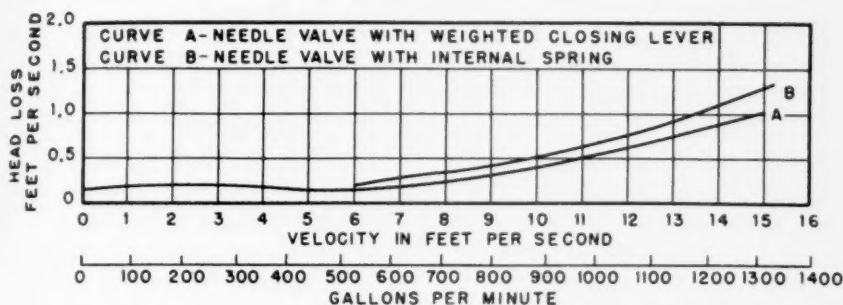


FIG. 5. Head Loss Through Two 6-Inch Needle Type Check Valves

lying in variations in the degree of suddenness of the enlargement of the body passage downstream from the disc.

Referring to Fig. 4, Curves A to E show the loss through a valve of the long body type with various amounts of closing torque applied to the spindle by means of an external weighted lever, while Curve F shows the loss through a valve of the same type equipped with a spring-actuated lever. Curve G shows the amount of spindle torque applied by the spring on the valve for Curve F at various velocities of flow. From these curves it becomes evident that there is little advantage in using oversize valves when high closing torques are required to prevent slamming, as the loss through these valves is fairly constant at all practicable velocities. The figures at various points along these curves indicate, in degrees of arc, the position of the disc at different velocity points. Referring again to Fig. 2, it will be noted that the relatively small amount of torque applied to the valve in the upper curve is sufficient to eliminate the surge on the pump

side of the valve almost completely. This system, however, is subject to a rather severe pressure surge, and, in consequence, severe slamming is absent even with no torque applied to the valve. On the other hand, the excessive torque applied to the 3-inch valve in Fig. 1 (bottom curve) was not sufficient to eliminate entirely the slam in the system containing a hydro-pneumatic tank.

Referring to Fig. 5, the losses through two valves of the needle type are shown. Valve A in this case was equipped with an external weighted closing lever while Valve B was equipped with an internal spring. These valves have low losses, but they are open to the objection that the internal parts are inaccessible without removing the valve bodies from the line.

Mention has been made of the possibility of substituting automatically controlled, hydraulically operated gate and plug valves for check valves. These valves are rather costly and introduce complication into control schemes which, it would seem, makes their use in small and medium sized plants unjustifiable.



## Maintaining Efficiency of Motor-Driven Centrifugal Pumps

*By L. V. Schuerholz*

IN SELECTING motor-driven centrifugal pumps, it is advisable to specify the highest possible unit efficiency so that the greatest output for the least cost may be obtained—the saving in power cost per percentage efficiency being directly proportional to the size of the unit. The purchaser should, however, carefully ascertain that the initial efficiency is not based on excessively small ring clearances in the pump. Having installed efficient pumps, it is important to maintain the initial efficiency and hold power costs to a minimum in maintaining the maximum output. The reliability of a pumping unit is of greater importance than the actual percentage efficiency, and careful maintenance of all appurtenant equipment, including motor, controls, and circuits, should be closely observed so that the pumping unit may at all times be ready to serve.

For efficient operation of a pumping unit, it is necessary that a certain amount of auxiliary equipment be furnished. This equipment should include suction and discharge gages, of both indicating and recording types if possible. The indicating gage is used for frequent visible check-ups on the pump performances, and the charts produced by the recording gage are kept as a permanent record. If the installation does not warrant the use of both types, the recording gage is preferable because it may be used to serve both purposes.

Some flow metering device such as the Venturi type meter, having both indicating and recording attachments, should also be included in the auxiliary equipment. The use of such a device makes it possible for the operator to determine the output of the pump at any time, and also gives a pumpage record which can be used in conjunction with the suction and discharge gage charts to determine the actual output of the pump over a period of operation. The indicating portion of the flowmeter is also useful in showing the operator that his pump is not clogged, since such clogging would

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immediately precipitate a sharp drop in pump output. A break in the piping on the discharge side of the pump would be indicated by a sudden increase in the pumpage shown on the meter.

For observance of motor performance, an ammeter and voltmeter should be provided. These meters should be equipped with switching devices for determining the current and voltage in all phases, thereby making it possible for the operator to observe any line voltage drop or current unbalance which would seriously affect the efficiency of the motor. Wattmeters are not absolutely essential since the actual power input can usually be determined from the watthour meter of the power company.

Where the necessary auxiliary equipment is available, the maintenance of efficiency of the pumping unit resolves itself into a comprehensive study of the pump operation by the operator. One of the most important points to be observed is the pump output, as indicated on the flowmeter, since a sudden drop in output would indicate stoppage or clogging of the pump. Such stoppage is rather unlikely when pumping clear water, but it is a serious consideration when pumping solids in suspension, such as sewage, paper pulp, etc. The next consideration is prevention of excessive wearing-ring wear, since the efficiency of the pump may be seriously reduced by leakage past the wearing rings from the discharge volute back into the suction eyes of the impeller.

### **Wearing Rings and Pump Bearings**

When pumping sewage or similar liquids which carry solids, it is well to have some means of flushing the wearing rings. This may be accomplished by the introduction of a clear water supply to the rings. A clear water supply to the packing boxes of the pump should also be installed. When filtered water is being pumped, such a supply may be obtained easily by tapping the discharge of the pump, but when sewage is pumped, a separate source of supply of clear water is essential. The introduction of this water to the packing boxes seals the pump against leakage along the shaft from the pump suction and prevents the pump impeller from pulling in air when operating under a suction lift. This seal also makes it possible to operate a pump with less pressure on the packing, a slight drip from the packing glands being not only permissible but advisable. When the packing pressure is thus relieved, the wear of the packing on the pump sleeves is reduced to a minimum, packing remains in better condition and has longer life, and considerable friction is eliminated, tending to reduce heating and thereby to increase efficiency of the pump. When suction is taken from any source likely to contain foreign substances, such as a block of wood or sizable stones, a screen should be placed somewhere in the suction ahead of the pump, since the entrance of such foreign matter

into the impeller suction eyes may distort the pump vanes and seriously impair the pump efficiency.

From a maintenance standpoint, proper care of the pump bearings is of great importance. For instance, when sleeve bearings are used, lack of proper lubrication will result in excessive bearing wear. This, in turn, will allow the pump shaft to drop, causing shaft-sleeve and packing wear, and an increase in wearing ring clearance, directly affecting efficiency. Continued operation with faulty lubrication will also result in wear on the flexible coupling connecting the pump to its driving motor, and eventually in complete breakdown either from bearing failure or from some source directly traceable to bearing wear. Care should, therefore, be exercised by the operator to ascertain that the oil in the sleeve bearing is at the proper level and to determine at frequent intervals whether or not the bearing oil rings are rotating.

Oil level in the sleeve bearing should be indicated by a sight gage equipped with a permanent marker. Dust-tight covers through which rotation of bearing oil rings can be observed should be provided as part of the bearing construction. If ball or roller bearings are used, the operator must overcome the natural tendency to over-oiling to prevent the high temperatures which result from the thrashing of the lubricant, particularly at high speeds. Where grease is used as a lubricant it is also possible to cause high bearing temperature by overdosing. Regardless of the type of bearings used, the utmost cleanliness must be observed when draining and replacing the lubricant so that no grit or other foreign matter can enter the bearing housing, particularly where ball or roller bearings are used.

### Motor Maintenance

The maintenance of the motor is another important consideration, since the efficiency of the driver is just as important as that of the pump. The bearings of the motor should be just as carefully maintained as those of the pump, since all possibilities of trouble as already outlined are equally applicable. Excessive wear of motor bearings may result in a slight drop of the shaft and rotor, causing a variation in the air gap or clearance between the rotor and the stator windings. Such a variation would, in turn, create the possibility of local heating and overloading of the bearings, due to unbalanced magnetic forces in the motor, and would, in extreme cases, result in springing of the motor shaft to the extent of allowing the rotor to strike the stator winding, permanently injuring the motor insulation and causing complete breakdown.

Where open type motors are used, some method of cleaning the windings—preferably by blowing air across and through them—should be provided, for the formation of dust or grease on the insulation has a detrimental

effect on its insulating qualities. If the windings are not kept clean, the heat developed in them cannot be properly dissipated, since the dirt acts as a barrier or heat insulator, and a point of high temperature, or "hot spot," may develop. The capacity of all insulation is directly dependent upon its ability to withstand heat without deterioration, and the development of a "hot spot" will eventually bake the insulation at that point, causing it to crack and fall off, leaving the bare coils exposed and a resultant short circuit or ground. Most motors are equipped with fan blades to promote the circulation of air through the windings. Such fans should be kept clean so that they will not act as a means of depositing dust in the windings. As a further precaution, it is good policy to install a pumping unit in such a position that the motor will have abundant free air circulation.

When wound rotor motors, particularly those employing external resistance to vary the speed, are used, care should be exercised in maintaining clean, smooth collector ring and brush surfaces and proper brush tension so that the motor will run at exactly the speed desired. On motors of the wound rotor type which use an external resistance for starting only, the same precautions are necessary to insure proper starting.

### Couplings and Controls

Some consideration should also be given the flexible coupling connecting the pump and the motor, particularly the types which incorporate in their design parts which require lubrication. The coupling should be checked at intervals to ascertain that the proper amount of lubricant is always present; otherwise excessive wear will soon develop. Although flexible couplings of all types are designed to permit misalignment, this should never be an excuse for not aligning the pump and motor properly in the original installation, or for operating the unit out of alignment if such a condition should occur through vibration or other causes.

Maintenance of control is also very essential, and much trouble can be eliminated by as extensive use of automatic or semi-automatic control as practicable. Control of this type can be so arranged that the operator is required only to press a button to start or stop the pumping unit, so that mistakes in starting sequence, which might occur under hand control, are eliminated. Cleanliness of all control equipment is just as important as cleanliness of the pump and motor, both from the standpoint of insulation life and of maintenance of good contact surfaces on switching equipment. Clean contacts and proper contact pressure should always be maintained on all switching equipment to prevent excessive contact temperatures; and these temperatures should be checked periodically by the operator.

When variable speed wound-rotor motors are used, the secondary resistors should be checked occasionally for loose connections and excessive resistor temperatures, since such conditions, as well as poor contacts on switching equipment, may seriously affect the speed of the pumping unit. In the installation of such resistance grids, they should never be stacked in high tiers, since the heat from lower portions of the tiers will decrease the capacity of the grids in the upper portions. Grids should be stacked to provide ample ventilation and, preferably, should be mounted individually to facilitate removal for repairs or replacement. Full accessibility is necessary for the proper maintenance of this portion of the control equipment.

If all the foregoing points are carefully adhered to, it should be possible to hold unit efficiency at a maximum. Regardless of care in equipment maintenance, however, a routine performance check should be made by the operator or engineer in charge. This check should include regular readings of all instruments, since a log of these readings is essential for a determination of quantity-head output against kilowatthour consumption.

**Discussion by Stanley E. Kappe:**\* Mr. Schuerholz has presented a very thorough discussion of the equipment needed for tests, and of the points which should be checked and given proper attention, to maintain maximum wire to water efficiency of the pumping unit. If the operator were to follow these suggestions, he would undoubtedly obtain the greatest output at the least cost.

It is surprising to note, however, that very few operators actually try to maintain the maximum possible efficiency of pumping units, or even know what the efficiency of these units was at the time of their installation. Information concerning original efficiency and characteristic curves of pumps should, of course, be available to every operator.

In his work the writer has had the opportunity to observe the situation throughout the country, and has found this practice, or lack of practice, to be common. In a majority of cases, the answer to inquiry concerning frequency of efficiency determinations on pumping units has been, typically: "Never—we lubricate them, repack them when necessary and run the units until they can no longer deliver the amount of water required, or until they break down. When this occurs, we attempt to repair them [mostly locally, by unqualified workers] and, if this is not possible, we buy new ones."

Recognizing this situation, it may be well, here, to point out just what

\* Research Engr., Chicago Pump Co., Washington, D.C.

efficiency is. Overall efficiency, according to the standards of the Hydraulic Institute, takes into account all the losses in the pumps and the driver, including gear if used, and indicates the economy of the entire unit; but does not include the piping system and its head losses, nor the wiring system and its losses. Motors are usually sold on the basis of conventional efficiencies, which are not necessarily true efficiencies. Manufacturers will, upon request, furnish guaranteed efficiencies made by direct measurement. In measuring power to an electric motor, the measurement should, again according to the standards of the Hydraulic Institute, be made at the motor and not at the switchboard; thus losses between the board and motor will not be included.

### Modern Design Methods

It should be kept in mind that the design of higher pump efficiencies has been brought about by more precise manufacturing methods, the gradual evolution of design of water passages and impellers, certain design relationships between vane angles and peripheral velocity of impeller and entrance areas, and the maintenance of a close running fit between the runner and the wearing rings to minimize the leakage and recirculation of water back into the suction eye. When the pumps are new, the losses of energy result from friction in bearings of the impeller shaft, friction of water against casing and impeller and internal skin friction of the water as it changes shape and velocity in passing through the pumps, as well as from recirculation within the pump and loss in conversion into pressure of the kinetic energy of water leaving the impeller. After the pumps are in service for some time, wear, corrosion or erosion will take place and change the proportions in the impeller-casing design, resulting in a decrease in efficiency, followed by noisy operation and vibration due to cavitation.

Many operators have their worn impellers rebuilt locally or in the water works machine shop. Care should be taken to rebuild and balance the impellers properly or the work may be very costly in the end. Before any work is planned prices should be secured from the manufacturer. In the case of small pumps it is often cheaper to purchase a new impeller than to repair an old one.

If the pumps are using too much power, the decrease in efficiency may be caused by a bent shaft or by binding of the rotating elements; stuffing boxes may be too tight; wearing rings may be worn; or the casing packing may be defective. It has been reported that leakage of air through worn packing will cut the capacity of the pump without reducing the input to the motor. Decrease in pump efficiency may be caused too by the springing of a base plate in shipment or the unit may be distorted by an uneven foun-

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dation support or by pull from connections made to the suction and discharge nozzles. Such conditions may place abnormal stresses on the bearings and cause binding or metal to metal contact of the rotating elements.

Mr. Schuerholz pointed out that excessive wear of wearing rings materially affects the efficiency of pumps and that initial efficiency should not be based on excessively small ring clearance. These points should be emphasized. George J. Poole, Supt. of Pumping Stations at Minneapolis, for instance, found that the efficiency of smaller pumps decreased more quickly than larger ones because close ring spacings and higher speeds caused faster wear and erosion.\* He found that pumps having capacities of about 750 gpm. dropped 4 per cent in efficiency in one year and that this loss could be recovered by wearing ring replacement. The rapid wear of wearing rings may also be caused by shaft deflection and shaft whipping.

Whether it is economically warranted to make repairs to increase efficiency depends on local circumstances, but this is a fact that can easily be ascertained. The cost of pumping 1,000 gpm. against a head of 1 ft. with 100 per cent overall efficiency requires 0.189 kw.†

If bearing housings run too hot, bearings should be checked. Drag may be caused by over-lubrication or by the use of improper lubricants. Graphite should not be used. Such a condition may also be caused by high spots on the ball bearings or by uneven wear of the bearings due to defective bearings or rust spots. The importance of checking bearings has already been pointed out.

### Suction Conditions

Among the most important factors that may affect the operation of centrifugal pumps are the suction conditions. The characteristic curves of the pump, when operating under a suction lift, will be different from when it is operating under a positive suction head. Abnormally high suction lifts usually cause serious reduction in capacity and efficiency of the pump and often lead to serious trouble from vibration and cavitation. Suction piping for double suction pumps should not include elbows close to the suction nozzle, except when they are placed in a vertical position. Elbows should be of the long radius type. If improperly placed, the uneven flow of water through them will cause more water to enter one side of the impeller than can enter the other side. As a result, there will occur a reduction in capacity and efficiency, and a thrust, which will heat the thrust bearing and be of sufficient magnitude to cause rapid wear of the

\* POOLE, GEORGE J. Maintaining Efficiency of Centrifugal Pumps. Jour. A. W. W. A., 33: 849 (1941).

† Handbook of Water Control. California Corrugated Culvert Co. (1940). p. 167.

bearings. Decrease in efficiency can be caused by any condition that may cause turbulence on the suction side of the pump, so the pump should never be throttled by closing the valve on the suction side.

Centrifugal pumps, particularly those operating at high heads, require much less power when started with their discharge gate valves closed than when started at rated capacity and head with the valves wide open. Depending on the type of motor used, then, some saving in power can be effected by taking advantage of this fact.

Every plant should be provided with means of measuring the output of each pump, and should have a definite program of testing its efficiency. This is only good practice, and a practice that will usually pay large dividends.



## Maintenance of Control Equipment in Water Purification Works

*By Alan A. Wood*

**M**ANY water works men, no doubt, are already experiencing difficulty in obtaining supplies and equipment for the maintenance of essential apparatus in their plants. Unquestionably this situation will become progressively worse as the present emergency continues, so that new equipment, except for plants directly engaged in the national defense effort, will be increasingly difficult, if not impossible, to obtain. In view of this, the title of these remarks might well be "Making the Most and Best of What You Have." It has always been desirable to keep mechanical apparatus in first class condition, but now these emergency conditions have made the maintenance of a high level of efficiency at all times an absolute necessity.

In the largest water works and sewage disposal plants, complete maintenance equipment, including machine and hand tools, chemical laboratories, plumbing and even sheet metal shops, has usually been provided, whereas meter testing and repair shops have almost invariably been considered a necessary part of the plant. In such large plants there is a possibility of greater specialization in the division of responsibility, so that the individuals comprising the maintenance organization may become expert in their particular duties. Equipment can readily be disassembled, cleaned, oiled and replaced, all in a minimum of time. Some plants, in fact, are so elaborately equipped with machine tools and personnel that they actually manufacture some pieces of equipment, e.g., valves and hydrants, in their own maintenance shops. That, however, seems to be carrying the matter of maintenance beyond reasonable limits.

The operator of the small or medium sized plant is not usually so blessed with advantages. In some cases he is obliged to assume the positions of filter plant operator, chemist, mechanical superintendent and meter tester as well as supervisor of the laying of new mains and of the installation of valves, hydrants and service connections. Because of this apparent disadvantage, however, he often develops a natural skill and ingenuity in

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making the most and best of what he has. Even in the best of times appropriations for new apparatus are often difficult for him to get; so, in many cases, he must make gadgets or improvisations to maintain the effective operation of his plant. Several such small plant operators have made important contributions to the design and improvement of existing equipment, which have later been accepted and developed by the industry. A few of them have developed appliances in their plants and later organized substantial enterprises for their manufacture and sale. Most frequently, however, the principal return to the plant operator is his satisfaction in keeping his plant in first class condition and the contribution to his reputation as an operator.

### Plant Appearance

The first principle of plant maintenance is plant appearance. There is no plant so small, so remote or so poorly endowed financially that, within reasonable limits, it cannot be maintained. Proper maintenance is largely a matter of good housekeeping—the plant must be kept clean. The tools for the purpose are simple and inexpensive. A broom and a mop, together with plenty of soap and water, can, and do, work wonders. Paint though slightly more costly is still the least expensive method of maintaining surfaces.

It is at this point, however, that climate, location and, to some extent, design become factors for consideration. It is difficult to make paint adhere to a damp surface. In the pipe gallery of a filter plant, much of this trouble can be avoided by keeping the valve glands tight and well packed with suitable material. In some areas and in some seasons of the year, however, it is virtually impossible to prevent the condensation of drops of moisture on pipe lines and mechanical equipment. Several cork-base insulating preparations have been developed for application on pipes to inhibit the deposition of moisture. These insulators are somewhat expensive and difficult to handle, but, if properly applied, they greatly improve the appearance of the plant, particularly if covered with an attractive paint. The use of such coverings is perhaps financially impossible in some cases, but a suitable paint covering is available to almost every plant.

A pipe gallery that is well lighted, preferably by natural illumination, is particularly helpful in keeping all fittings, flanges, stuffing boxes and glands tight. If natural illumination is not available because of design, thought may be given to improving the artificial lighting to eliminate the dark corners which eventually become repositories for dirt and odd pieces of equipment. White painting of these corners often helps keep them clean.

Beyond these general points of maintenance practice is encountered the problem of maintenance of controls in water works and filtration plants.

In this discussion the term "controls" is used rather broadly to include: float controls or regulators for pump starting equipment, Venturi meters and Venturi rate of flow controllers, clear well controls, chemical feeders—both automatically and manually operated—, chlorinators, water level gages, pressure gages, temperature gages, thermostats, etc. Perhaps the best point of departure for such a discussion is to take a hypothetical problem which demonstrates the need for the institution of sound maintenance procedure and to attempt to point out the various steps in its solution.

### **Institution of a Maintenance Program**

It may be assumed then that a new superintendent has just been placed in charge of the operation and maintenance of a small water works and filtration plant located in a remote part of the state. The plant is of adequate size and capacity, but has been "run-down" for some time. The local engineers of the State Board of Health have been critical about the results obtained. Funds for repairs and replacements have not been too plentiful, and, though the town is in a better financial condition now, materials and apparatus are hard to get.

Faced with this situation, the first thing the superintendent should do is to procure, if possible, a set of the original plans and specifications under which the plant was constructed. Regardless of the superintendent's opinion of the design of the plant, of course, few, if any, changes could be made under the circumstances—in other words, he would have to "make the best and most of what he had." To do this, the plans would give him the ideas of the designers and some concept of the capacities and limitations of the plant as well as of the purposes and limitations of the equipment. This would enable him to estimate his resources and to itemize the potential output of each piece of apparatus in the plant.

Next, he should try to locate the manufacturers' drawings and instructions for every piece of mechanical equipment in the plant. If these are not available in plant files, he should request duplicate sets from the manufacturer, who, as a general rule, will furnish them either free of charge or at a nominal cost. From these specifications and instruction books, then, he would learn how design capacity of the apparatus compared with present performance.

These comparisons and/or tests are usually very simply made. For testing the performance of an effluent rate controller, for instance, one may use a stick, 1 in. square and 4 or 5 ft. long, with a nail driven through it at right angles to the axis and bent into a hook, to make a satisfactory hook gage. Then, by cutting off the influent valve on each filter, one may observe the accuracy and efficiency of the rate of flow controllers and gages by

taking the fall on the filter for a certain specified time. This is the simplest of all rate controller tests, but no better one is known. A stop watch would be a desirable, though not an absolutely essential, piece of apparatus for this and many other tests. It is, however, well worth the few dollars it costs.

Similarly, loss of head gages can readily be tested by comparing the deflections in float tubes, diaphragm pendulum units or mercury wells with heads of known magnitude. There is absolutely no excuse for permitting any simple loss of head gage or water level gage to remain out of adjustment for any length of time. A simple manometer for water, mercury or carbon tetrachloride comparisons can be made of a glass U-tube mounted on a board. Better instruments can be purchased at a reasonable price, but any operator can construct a manometer, satisfactory for most purposes, from materials found in any small chemical laboratory.

### **Manufacturers' Maintenance Service**

As a rule, equipment manufacturers maintain a field service force. Users of the more complicated pieces of equipment will do well to consider the advisability of having periodical inspections, overhaul and readjustments made by these factory-trained experts. Most manufacturers keep charges for this service as low as possible in an effort to encourage its use, because the expert attention assures the best results from the equipment and, therefore, the highest consumer satisfaction. Water works equipment needs the occasional attention of a specialist.

To digress for a moment, it may be suggested here that operators become acquainted with the manufacturers of their equipment, both by correspondence and through contact with their representatives. If a manufacturer's service man is employed, the operator would do well to stay with him while he is on the job, for in so doing he will learn a great deal about his equipment and will be better able to make minor adjustments from time to time as they are found necessary. Often, too, valuable information can be obtained simply by writing to the manufacturer. In this respect, however, it is suggested that specific details regarding size and type of machinery as well as the symptoms of trouble, if any, be given. Simply to say, "This damned thing don't work!" is not only bad English but poor engineering, because most pieces of apparatus built by a reputable manufacturer will work satisfactorily if installed, operated and maintained properly.

### **Special Control Features**

Many control instruments contain either metal or rubber diaphragms. Rubber diaphragms are very durable when used under water, but if exposed to air and sunlight they soon lose their usefulness. If a diaphragm is

frayed or punctured, it should be thrown away at once rather than left where it can be picked up and used by someone else. One ingenious operator repairs broken diaphragms with a cold patch of the type used on tire inner-tubes, but this practice is not recommended. Little can be done, either, with strained or broken metal diaphragms. Experience has proved that the safest practice is to discard and replace them immediately.

Dirt, rust and scale are the enemies of efficiency in control apparatus. Cleaning compounds, mechanical removal of scale and rust and the application of paint are all important in the maintenance of water works apparatus. A word of caution should be given, however, against too close adherence to the policy of "Save the Surface and You Save All." Several cases where enthusiastic maintenance men have painted, not wisely, but too well, may be cited. Paint splashed over revolving or sliding shafts, knife edges or packing glands will probably do more harm than good. Oil, too, should be handled carefully to keep it away from rubber diaphragms or rubber packing.

Occasionally the question of frequency of overhauling water works equipment arises. This is particularly difficult to answer because such factors as age of equipment, its complexity, and its subjection to the action of chemicals must all be considered. In general, however, a year would seem to be the maximum interval and six months the minimum. These limits must be qualified, of course, according to the type of equipment.

### Minimum Requirements in Replacement Parts

It seems essential in these unusual times to keep on hand a supply of repair or replacement parts for control equipment. Although it is not in the interest of national defense for water works and filter plants to order or maintain large supplies of repair parts, it is important to keep minimum requirements of these supplies immediately available. Following is a list of replacement parts and supplies for meters, rate controllers and rate of flow, water level, electric telemeter and wash water gages, which will give an indication of this required minimum:

*Venturi Meter Instruments:* 1 set main shaft packing; 1 main shaft; 1 set rubber gaskets; 1 lb. mercury; 1 pen; 1 pen arm; and 1 package miscellaneous screws.

*Rate of Flow Controllers:* 1 diaphragm; 1 air valve; a supply of stuffing box packing or hydraulic cylinder packing; and 1 package miscellaneous screws.

*Diaphragm Pendulum Units:* 1 diaphragm; flexible hose for stuffing box; and a spare pilot valve, if required on the particular apparatus.

*Loss of Head and Rate of Flow Gages:* An adequate supply of "Ashaway" cable; 1 pen; and 1 pen arm.

*Water Level Gages:* A supply of  $\frac{1}{32}$  in. "Phosphor Bronze" cable.

*Telemetering Gages or Meters:* For the transmitter: 1 mercoide switch; 1 cam shoe and arm assembly; and 1 spare motor. For the receivers: 1 spare motor.

It should be remembered that any brand of equipment which has been sold successfully over a period of years must be good. Manufacturers of poor equipment soon fall by the wayside. Even though a plant is poorly equipped, however, is no cause for despair. In many cases, even discontinued models have a life expectancy of many years of satisfactory service. In general, it must be admitted that most of the troubles with water works equipment are due to faulty application on the part of the manufacturer or the engineer, faulty installation or unfamiliarity with the equipment on the part of the operator.

The operator is and should be the best friend of the manufacturer. From the operator the manufacturer gets most of his ideas on the improvement of apparatus. It must be remembered that though the manufacturer makes the machine, in most cases he never uses it. A free exchange of ideas is, therefore, to the best interests of all concerned.

**Discussion by R. A. McQuade.\*** In his paper, Mr. Wood has discussed a subject of the utmost importance to all water purification plant operators and has presented much information of value to the proper maintenance of control equipment. One of the points brought out, with which the writer agrees emphatically, is that of the necessity of plant cleanliness and proper illumination. Regardless of the age of the plant, there is no reason why it should not be kept clean, painted and well lighted at all times. Appearance as such is one index of plant efficiency, and though cleanliness alone cannot, of course, overcome faulty operation or the ills attendant to incorrect design, it does indicate that the best possible attention under the circumstances is being given.

Another, undoubtedly more important, index of plant efficiency is the condition of equipment. Here, the point to be emphasized is that there is no reason why any part of the equipment should be allowed to remain idle or in poor operating condition. Though there may be extreme cases where this is necessary temporarily, in most plants the slight extra expenditure of time and money required can in no sense balance the loss of efficiency and of vital operating records that result.

In his discussion of this subject, Mr. Wood referred to the desirability of consulting manufacturers' field engineers regarding the testing and repair of

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\* Asst. Sales Mgr., Simplex Valve & Meter Co., Philadelphia.

complicated apparatus. Unquestionably this is proper practice with regard to such equipment as proportionate controls, summation units and the various forms of electrical transmission. With regard to the simpler types of apparatus, however, it is possible for the operator to make his own adjustments and simple repairs without outside assistance. If each operator were to familiarize himself with the salient points of each piece of equipment he could learn to make minor adjustments easily and could, thereby, save many hours or days of waiting for the field engineers to reach the plant.

Service engineers, too, are always happy to pass on information concerning their experience and knowledge. By close contact with the service man on the job, the operator can learn not only the principles involved in the construction of his equipment, but the short cuts of technique in repairing and adjusting it, all of which will make possible more efficient operation. A particular knowledge which can be gained by working with the company representative in his installation or repair of the equipment is that of the points in each type of apparatus which require special attention. Some of these danger points are pointed out in the following discussion.

### Maintenance of Controllers

In general, controllers are simple enough so that the informed operator can take care of their maintenance without help. There are, however, six points which require special attention:

1. In assembling the controller, all parts, particularly the diaphragm pot, must be properly leveled.
2. The knife edges should be watched to see that they are properly seated.
3. Piping connections from the Venturi section to the diaphragm pot should be carefully checked to ascertain that they are tight at all times.
4. If the controller does not seem to "take hold," two possible reasons should be investigated: (1) the connecting cable may have slipped from quadrant on which it should ride; or (2) the diaphragm may have been ruptured.

In the first case the remedy is simple, correction being made by lifting the scale beam, thereby slacking off the cable and making it possible immediately to place it on the quadrant. If the diaphragm is ruptured, however, the only solution is to replace it. To do this the diaphragm pot can be dropped by unbolting it from the main frame.

Diaphragms are made of a special resilient rubber. In the controller they have a rolling motion and therefore must be pliable. Failure generally arises from the presence of either air or sand and grit, air causing a "puncture" and sand or grit rubbing a spot thin till eventually it ruptures. Even

a small pinhole will cause trouble and necessitate replacement of the diaphragm. Patching should not be attempted, as the clearance between the piston and cylinder is small and the patch will impede the rolling motion of the diaphragm.

Replacement technique will not be mentioned here as it is explicitly described in the instruction books, but it should be pointed out that every operator should become familiar with the procedure. Diaphragms have a normal life expectancy of from two to five years, depending on their service, so they are not apt to be a continual source of trouble, but they do require constant watching.

5. Stuffing boxes also require close attention. They must, not only be filled with packing at all times, but with the right kind of packing. Excessive shaft friction in the stuffing boxes should be avoided by using the type of packing recommended by the manufacturer and by ascertaining that the packing cups are screwed down hard enough to stop leakage, but not too hard.

6. Air-binding is the final point of danger. In devious ways air finds its way to the diaphragm pot and, if enough accumulates, forms an air cushion which prevents the controllers from responding truly to the applied water differential pressure. The remedy is simple. Both the effluent valve and the small valves in the pressure connecting lines of the controller are closed. The counterweight on the scale beam is then placed at zero to remove the load on the piston and a plug in the bottom of the pot removed, so that, by cracking the effluent valve and the main pressure valve, a small portion of water finds its way to the upper side of the piston, driving it down and expelling air from its under side through the plug opening. Air on the upper side can be removed by reversing the procedure, i.e., by opening the throat pressure valve and a petcock in the side of the diaphragm pot. Any existing air will then be bled through the petcock.

### Maintenance of Gages

The standard form of gage is so simple in construction that any operator should be able readily to assimilate its details and operating characteristics and make minor adjustments. The troubles that usually occur, and which should be within the operator's ability to overcome, are few in number. They consist of air binding, friction-producing sheaves, broken or knotted cables and improper setting. If the gage is to be examined thoroughly it is a simple matter to disconnect the header from the differential pressure device and dismantle and clean it, but if it is desirable to check the gage without dismantling, the following procedure should be followed:

1. A check should be made for entrained air in both rate and loss cylinders. The remedy in both cases is to close the low pressure valve and

open the equalizing valve in the cylinder piping. The counterweight attached to the gage cable should then be lifted and jiggled up and down a few times. Any air trapped in the float will be released instantly.

2. The sheaves that may be used in the gage construction should be examined to determine whether or not they are free to turn and are properly aligned with the cables. The adjustable bearings should then be checked, first for tightness and then to ascertain that no paint or other protective coating is impeding their movement. For safety's sake the bearings should be lubricated with a light oil.

3. The wire cable portions of the connecting linkages should be examined for kinks or knots. The setting of the gage depends on keeping the cable straight at all times. If a kink occurs the cable is shortened, and, unless the gage pen or pointer is adjusted to suit the new condition, the reading will be off a trifle. Further check should then be made to make sure that the cable on the gage sheave is securely held under the cable clamp screw put there to prevent the sheave from slipping.

4. The setting of the pen or pointer should be checked for correct position. Preliminary to this, the water manometer should be applied to the gage, using the test pan, glass and scale provided with the instrument. When the gage has been calibrated, by subjecting the float to differential water pressures which correspond to certain rates of flow through the controller, a zero setting stop can be applied to the connecting links. The stop is a small collar which, when clamped to the link, prevents linkage from moving beyond a certain point in one direction by contacting a stop bracket attached to the gage. From this indication of the zero point, the pointer or pen is adjusted to the zero mark on the dial by means of a knurled disc on the pointer or pen shaft.

5. In recording gages, special care should be taken to keep the pens clean. Pens are of the capillary type and depend upon clean passageways for efficient operation. Special pen cleaning wires can be purchased for a few cents each, and, by their judicious use, a glass capillary pen can be kept in good condition for many months at a time. Substitute inks should never be used.

If the instrument is subject to much handling, e.g., in the changing of charts, care should be taken that the pen arm be kept in adjustment with the chart. This can be done by means of a small tangent adjusting screw located on the hub of the pen arm and requires only a few seconds.

### Maintenance of Metering Devices

Since the design of most plants includes some form of meter, a few remarks should be made with reference to this type of instrument. It will be best, however, to confine the discussion to the mercury float-operated

type, although other forms, such as air-drive, water float-operated, weir and flume meters are often used.

The mercury float instrument falls almost in the category of the mercury gage as far as checking and testing are concerned. Suspicion regarding the accuracy of the meter readings should be verified; and sources of trouble determined by checking several points of danger:

1. It should be determined whether the Venturi tube is clean and free from obstruction and whether the pressure lines from the tube to the instrument will permit the free passage of water. If clean filtered water is being measured, the possibility of clogging in any form may be almost totally discounted, but if raw or sediment-bearing liquid is involved, the pressure lines may be clogged. The remedy is a thorough blowing out of the lines to remove deposits. In extreme cases new pressure piping may be required.

2. Pressure lines should be examined for leaks, for grade and for air pockets. Leaks in a line will cause inaccurate readings. If grade and air pockets do not agree with the manufacturer's instructions, the grade should be changed or provision made for petcocks to vent air accumulations to provide free waterways through the pipes.

While the pipes are being checked for air pockets, the meter should be examined to determine whether or not any entrained air has reached the cylinder. All meters have some form of air ventilating arrangement for just such an emergency, and each instrument should be vented periodically.

3. If no fault is found in the tube or pressure lines, the instrument itself is almost surely the offender. The mercury level should be checked with the gage provided for this purpose. Loose connections sometimes allow a small amount of mercury to leak out over a long operating period.

4. Finally stuffing boxes should be examined to ascertain that they are properly packed with the correct type of packing. A grease gun is provided for this purpose, and, by means of a screw plunger incorporated in the stuffing box, the packing can be kept in contact with the pen arm shaft at all times.

It is not the purpose of this discussion to offer a panacea for all the ills of meters and controls, but to bring to the operator's attention a few of the remedies applied by manufacturers' service men. Although the need for these representatives will, no doubt, never be eliminated, it is believed that operators can, by adopting as many of their techniques as possible, improve maintenance programs on their own initiative and place themselves in a better position to provide uninterrupted operation in all its phases.



## Application of the Hardy Cross Method to the Analysis of a Large Distribution System

By *W. D. Hurst and N. S. Bubbis*

WHEN, in 1936, Professor Hardy Cross published his "Analysis of Flow in Networks of Conduits or Conductors" (1), he gave the designing engineer a powerful tool with which to attack the problem of designing, or improving the design of, existing water distribution systems. Following his work, Doland (2, 3), Fair (4, 5), Dodge (6) and Shand (7) published articles in which they described simplified applications of the Hardy Cross method to water works grid systems of distribution. All of these latter papers confined themselves to explaining various simplified applications of the Hardy Cross method, using a simple network as an illustration. None of them dealt with the problems involved in applying this method of analysis to a large water distribution system. Later, papers by C. K. Hurst (8) and Farnsworth and Rossano (9), however, did describe actual applications of the method.

The authors of this paper made an analysis of the water main distribution system of the City of Winnipeg in December 1938, their work being carried out by direction of W. P. Brereton, City Engineer. This description of the work is presented in the hope that the methods used in the analysis may prove of assistance to other engineers engaged in similar work.

The City of Winnipeg, with a population of 225,000, is situated at the junction of the Red and Assiniboine Rivers, in the Province of Manitoba, Canada. Its first water supply system was constructed and operated by the Winnipeg Water Works Co., a private concern. The system went into operation in 1882. The source of supply was the Assiniboine River, the intake and pumping station being located on the north bank of the river just east of the Maryland Street Bridge (see Fig. 1).

By 1895 it was evident that the source of supply and the service rendered by the company were not adequate for the rapidly expanding city.

A paper presented on October 9, 1941, at the Minnesota Section Meeting, Minneapolis, Minn., by W. D. Hurst, Water Works Engr., and N. S. Bubbis, Designing Draftsman, City of Winnipeg, Man., Canada.



reservoir system, the aqueduct was carried through the city streets to the existing reservoirs. The aqueduct west of, and including, the Red River crossing was designed to carry full distribution system pressure so that if it were later decided to construct a new pumping station and reservoir system in the eastern part of the district, the aqueduct could function as part of the water distribution system. This has not as yet been done.

The Greater Winnipeg Water District is an inter-municipal corporation which operates the source of supply, the intake and aqueduct, and supplies water in bulk (not under pressure) to the various municipalities making

TABLE 1

*Area of Units of Greater Winnipeg Water District and Water Supplied to Each*

UNIT	AREA	TOTAL WATER USED DURING 1940	PERCENTAGE OF TOTAL WATER USED
	<i>sq. mi.</i>	<i>gal.</i>	<i>%</i>
City of Winnipeg (all).....	24.94	5,919,846,785	87.77
City of St. Boniface (part).....	5.31	347,128,377	4.56
Town of Transcona (part).....	4.27	257,793,730	3.66
Munic. of St. Vital (part).....	2.15	60,625,123	0.86
* Munic. of Fort Garry (part).....	4.36	74,147,990	1.05
* Munic. of St. James (part).....	7.27	239,299,003	3.40
* Munic. of West Kildonan (part).....	2.38	47,666,497	0.68
* Munic. of East Kildonan (part).....	2.95	70,768,031	1.00
* Town of Tuxedo (part).....	0.69	30,595,315	0.43
<i>Total</i> .....	54.32	7,047,870,851	100.00

*Water Supplied to Areas Outside District*

* Canadian Pacific Ry. (North Transcona).....	4,085,777
* Munic. of Charleswood.....	6,793,870
* Village of Brooklands.....	1,651,932
* St. Vital Sanitorium.....	6,316,500
<i>Total</i> .....	18,848,079

\* Supplied with water under pressure.

up the district. The city receives the water at its reservoir system, and stores, purifies, pumps and distributes the water to the city and to seven municipalities. Two other municipal corporations—the City of St. Boniface and the Town of Transcona—operate pumping stations and reservoirs and distribute water under pressure to their customers. Table 1 details the water used by the various units making up the district.

From Fig. 2 it is evident that the population of the city increased at a high rate in certain definite periods and that the water distribution system grew in the same fashion. Due primarily to the change in source of supply,

and secondarily to the building up of sections of the city at points remote from the pumping station at McPhillips St., it was necessary from time to time to reinforce the distribution system with main feeders. The sizes and locations of these feeders were determined on the basis of the best engineering design known at the time; but, as no simple rational technique was available, the method depended for the most part on the good judgment of the engineering personnel. Later, however, when the Hardy Cross method offered that simple rational method of analysis, the City Engineer was prompted to make a study of the distribution system in the light of new practice. Accordingly, in 1938, the authors were instructed to make such an investigation.

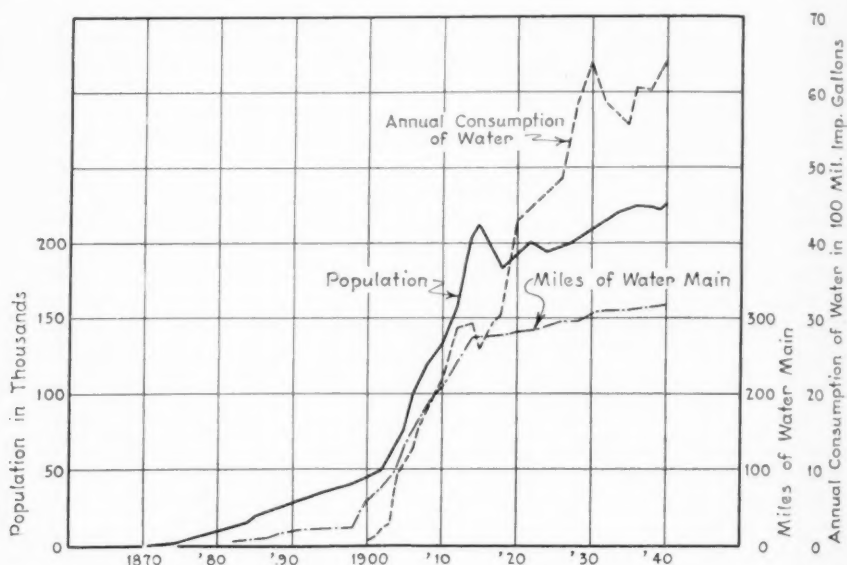


FIG. 2. Population, Annual Water Consumption and Miles of Water Main—Winnipeg, 1870-1940

### Outline of Distribution System

The district aqueduct crosses the Red River near Alexander Ave. (Fig. 1), at which point a 36-inch pipe is taken off to supply the city's high pressure fire service and subsidiary pumping plant at the foot of James Ave. The aqueduct then proceeds for 2.3 mi., discharging the water into the two reservoirs, located at McPhillips St. and Logan Ave. As the area of the city, to all intents and purposes, is practically level, and as the aqueduct delivers water to the reservoir system under a small head (about 12 psi.), all city water has to be pumped into the mains.

The main pumping station, having a capacity of 50 mgd.\* at 80 psi., is also located at McPhillips St. Two small pumps, with a capacity of 5.5 mgd. at 80 psi., are located at the James Ave. pumping station. The normal pressure carried at the pumping station is 75 psi.

The grid system of distribution is used. Large feeder mains run generally in a north-south and east-west direction, inter-connected by smaller laterals. Two geographic elements tend to disrupt this uniform grid—the two rivers and the railway yards. Ten feeders cross the two rivers and three mains cross the Canadian Pacific Railway yards. Due to the fact that the earlier source of supply—the artesian well system—was located in the northwest section of the city, that very sparsely settled section is well supplied with large feeders—mains which originally acted as the city's supply mains. As the pressure in the southeast section was somewhat low, a separate 18-inch feeder was constructed in 1930 to remedy this condition.

### Method of Analysis

To use the Hardy Cross method of analysis, described later, it is necessary to assume or otherwise determine points on the distribution system where the water is drawn off, together with the quantity of water drawn off from each. Obviously, consideration of all points of draft would complicate the analysis, so to simplify the work, the points of draft, called "take-offs," were consolidated into a lesser number of principal points.

It should be pointed out that, while any desired degree of accuracy of the distribution of flow can be achieved by the Hardy Cross method, once the location and quantities of take-offs have been determined, the actual accuracy of any specific problem depends on the proper selection of the take-off points and on the discharge assumed or determined for each. In other words, in the usual problem in which a known quantity of water is injected into a system of mains whose size is known, if the coefficient of roughness is properly selected, the degree of accuracy of the solution depends directly on how closely the determined take-offs approximate actual conditions. It is this phase of the problem that is hardest to work out accurately and that necessitates the greatest amount of work.

### Determination of Take-offs

To determine the location of and quantity drawn from each take-off, it was found necessary to make a study of a number of distribution system factors:

\* All values in gallons, except when specifically labeled (U.S.), refer to Imperial gallons. (1 Imperial gallon = 1.2 U.S. gallons.)

### 1. Total Maximum Hourly Rate of Flow for the City and Dependent Municipalities

The distribution problem of the city is complicated by the fact that the water works supplies water under pressure to several contiguous municipalities (see Fig. 1). As these municipalities are located at considerable distances from the pumping station, occasional complaints of low pressure, particularly under peak loads, were received. It was decided, therefore, to make an analysis of the distribution system, using peak loads as a basis of the study. The record pumping rates at the pumping stations

TABLE 2  
*Calculations to Determine Maximum Hourly Pumping Rate for Municipalities and Railways for July 1936*

SERVICE	TOTAL FLOW FOR MONTH	AVERAGE FLOW	FACTOR	MAXIMUM HOURLY RATE OF FLOW	PERCENTAGE OF TOTAL MAXIMUM PUMPING RATE
	mil.gal.	mgd.		mgd.	%
Munic. of St. James, Portage Ave. connection.....	16.9	0.54	3.0	1.62	4.42
Munic. of St. James, Sargent Ave. connection.....	15.6	0.50	3.0	1.50	4.09
Munic. of East Kildonan.....	9.0	0.29	2.25	0.65	1.77
Munic. of West Kildonan.....	10.3	0.33	2.25	0.74	2.01
Munic. of Fort Garry.....	8.0	0.26	2.25	0.58	1.58
Munic. of Tuxedo.....	6.5	0.22	2.25	0.50	1.36
Munic. of Charleswood.....	0.5				
Canadian Pacific Ry.....	10.7	0.35	1.0	0.35	0.955*
Canadian Pacific Auxiliary.....	6.0	0.19	1.0	0.19	0.518
Canadian National Ry., Fort Rouge.....	10.5	0.34	1.0	0.34	0.927
Totals.....	94.0	3.02	—	6.47	—

$$* \frac{0.35}{36.7} \times 100 = 0.955\%$$

up to the time the analysis was made occurred at 7:00 P.M., July 7, 1936—31 mgd. at McPhillips St. and 5.7 mgd. at James Ave., or a total of 36.7 mgd.

The month of July 1936 was unprecedentedly hot and dry. From July 5 to July 13, the maximum temperature varied from 92°F. to 108°F., with 106°F. on July 7. The total precipitation for the month was only 1.89 in., 1.72 in. of which fell on July 14. It can, therefore, be assumed that by far the greatest part of the additional water used in recording this

maximum pumping rate was used for domestic purposes—chiefly lawn sprinkling—while the commercial supply was comparatively unaffected. Since the average consumption for July was 19.57 mgd. and the total maximum hourly rate, 36.7 mgd., the ratio of maximum hourly to average daily flow was  $\frac{36.7}{19.57} = 1.875$ , or 1.88.

## 2. The Determination of Maximum Hourly Rate of Flow for the Dependent Municipalities and the Railway Systems

As it was the distribution system of the city proper which was to be studied, however, it was necessary to determine the various portions of

TABLE 3

*Number of Commercial Consumers and Annual Consumption of Water*

RANGE OF QUARTERLY CONSUMPTION	NO. OF CUSTOMERS	QUANTITY CONSUMED PER ANNUM
<i>1,000 gal.</i>		<i>mil. gal.</i>
Less than 100	2,680	210
101- 200	351	175
201- 400	292	303
401- 600	113	202
601- 800	37	91
801- 1,000	31	101
1,001- 5,000	50	333
5,001-10,000	8	197
10,001-15,000	—	—
15,001-25,000	1	73
25,001-50,000	—	—
More than 50,000	2	548
<i>Totals . . . . .</i>	3,565	2,233

the total maximum rate of flow used by each municipality. The municipalities served by city water are very largely residential districts, so to obtain their maximum hourly rate of flow, it seemed reasonable to multiply their average consumptions by a selected factor. The factor for the city proper, as determined above, was 1.88; for the metered municipalities, a factor of 2.25 seemed reasonable; and for the unmetered municipalities, a factor of 3.0 was thought not to be too high. Since the two railway systems are very large consumers of water, it was thought to be desirable, too, to determine the portions of the total maximum hourly rate of flow consumed by them. Table 2 presents the results of the survey.

### 3. The Determination of the Maximum Hourly Rate of Flow Attributable to Commercial Usage of Water

An inspection of Table 3, which shows the number of commercial consumers and their annual consumption of water, indicates that a consideration of each commercial consumer as an individual take-off would entail more work than consistent with the accuracy of the result. Therefore, there was made a detailed study of these consumers in the business and wholesale district, classifying them by type and amount of water consumed (Table 4). A study of these results indicates that no consumer whose quarterly consumption was less than 1 mil.gal. would have used a greater maximum daily average than  $\frac{1,000,000}{91.25} = 10,980$  gal., or only

TABLE 4  
*Number and Classification of Large Consumers in Business District*

NO. OF CUSTOMERS	RANGE OF QUARTERLY CONSUMPTION	HOSPITALS	APARTMENTS	HOTELS	BUILDINGS	CAFES	CHURCHES	SCHOOLS	MISC. CONSUMERS
	<i>1,000 gal.</i>								
125	100- 200		60	6	8	4	3	1	43
108	201- 400		76	4	6				22
26	401- 600		19		1			1	5
11	601- 800		3	1	1				6
9	801-1,000								9
15	1,001-5,000	2	1						12
1	More than 5,000	1							
295	—	3	159	11	16	4	3	2	97

0.03 per cent of the total maximum hourly pumping rate. It is also indicated that 169 of these 279 consumers are classified as apartment blocks and hotels, the residents of which would be shown on the population map referred to later and, therefore, should be dealt with in the same manner as individual domestic consumers. From Table 3 it can be determined that the consumers, whose quarterly consumption exceeds 1,001 mil.gal. each, use 51.6 per cent of the total water sold commercially and at the same time represent only 1.7 per cent of the total number of commercial consumers. On the basis of these facts, only commercial consumers whose quarterly consumption exceeds 1 mil.gal. were considered in determining the take-offs—apartments and hotels being excluded. The actual location of the take-offs and the quantities of water used by the group considered were then plotted on a map.

#### 4. *The Determination of the Maximum Hourly Rate of Flow Attributable to Domestic Usage of Water*

From Table 2 it was determined that the municipalities, together with the railways, would use 6.47 mgd. From a study of meter readings it was then found that the commercial consumers, exclusive of hotels and apartment blocks, whose quarterly consumption exceeded 1 mil.gal., would use 1.53 mgd. Subtracting these two figures from the maximum hourly pumping rate of 36.7 mgd. left a balance of 28.7 mgd., the city domestic hourly pumping rate.

#### 5. *The Determination of the Points of Take-Off and the Amounts Drawn Therefrom*

From the 1936 population of the city—224,998—and the maximum domestic hourly rate of flow—28.7 mgd.—it was determined that the maximum domestic hourly per capita consumption was  $\frac{28,700,000}{224,998} = 127.8$  gpd.

A map of the city (scale, 1,000 ft. = 1 in.), similar to Fig. 1, was then prepared, showing the feeder main system. All 10-inch and larger pipes were considered the principal feeders; 8-inch mains were also shown, but, in nearly all cases, were used only for determining the points of take-off. An equivalent pipe size was used to replace multiple mains.

From a population map of the city (1 dot = 50 persons), the population served by the feeder mains was plotted on the feeder-main map. By multiplying the population within a feeder area by the maximum domestic hourly per capita consumption (127.8 gpd.) the quantity used in the area was obtained.

The determination of the points of take-off was accomplished by the use of a typical grid system (Fig. 3). The figure in the center of each rectangle represents the population, in fifties, within that area. The figures at each corner of the rectangle represent an equitable distribution of the population included within the rectangle and assigned to each corner. Very often, where the population dots appeared uniformly distributed, the figure at the center was divided by four, one quarter being assigned to each corner of the rectangle. By following this same procedure for each rectangle, a condition as shown in Fig. 3 was obtained. Adding the quantities at point E, gives a sum of 28. It is therefore assumed that the quantity of water represented by the usage of  $28 \times 50 = 1,400$  persons is drawn off at point E and, similarly, an amount represented by the usage of 1,125 persons is drawn off at point F. Therefore, the quantity of water drawn from point E was at the maximum

hourly rate of  $1,400 \times 127.8 = 178,920$  gpd., and that drawn from point F was at the maximum hourly rate of  $1,125 \times 127.8 = 143,775$  gpd.

Take-offs from large commercial consumers were plotted where they were actually located and were assigned to the closest take-off point. Point J, for instance, shows the quantity drawn by and the location of a commercial consumer and it would be assigned and added to the take-off at point F. The quantities determined for each take-off were reduced to percentage of total maximum hourly rate of flow and were plotted as percentages on the work sheets.

A		B		C	
	8	8	9	9	4
					4
	32		36		16
D	8	8	9	9	4
	8	6	5	5	4.5
				J → 2	4.5
	24		20		18
I	4	6	5	5	4.5
					4.5
I		H		G	

FIG. 3. Typical Grid System

### Application of the Hardy Cross Method

The Hardy Cross method provides two methods of analysis: (1) the method of balancing heads, which satisfies the condition that the total flow into and out of each pipe junction is zero; and (2) the method of balancing flows, which satisfies the condition that the total change of head around each pipe circuit always equals zero. The fundamental principle of both methods is that the resistance to change of flow in any pipe equals approximately  $nkQ^{n-1}$ ; where  $kQ^n = h$ ;  $h$  = change in head accompanying flow in any length of pipe;  $k$  = loss of head in the pipe for unit quantity of flow (some engineers prefer the use of  $r$ ),  $k$  being a variable and depending on the length and diameter of the pipe and its roughness;  $Q$  = quantity of flow; and  $n$  = an exponent usually taken as 1.85 or 2, depending upon whether the Williams-Hazen or Darcy formula is used.

The method of balancing heads was used in the solution of the Winnipeg problem for reasons of convenience. The details of the application of this method are outlined in Figs. 4A, 4B and 4C.

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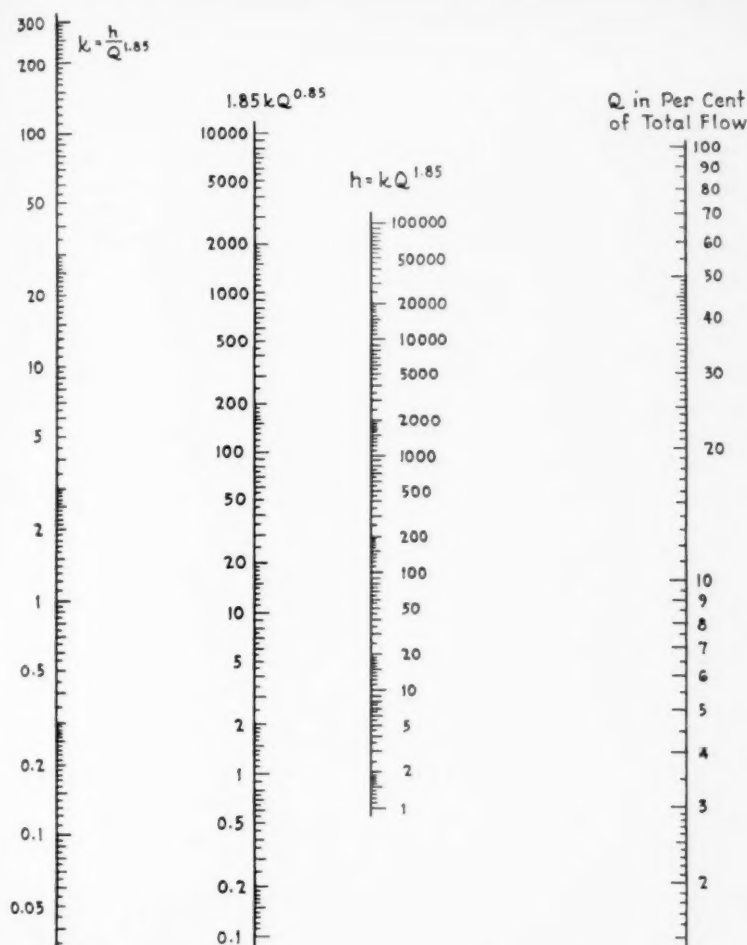


TABLE OF VALUES OF  $k$  FOR 1,000 FT. OF PIPE BASED ON WILLIAMS-HAZEN FORMULA  
Head loss in ft. =  $k \times 10^3 \times Q^{1.85}$  per 1,000 ft. (Q representing U.S. gpm.)

d	C=90	C=100	C=110	C=120	C=130	C=140
4	340	246	206	176	151	135
6	47.1	34.1	28.6	24.3	21.0	18.7
8	11.1	8.4	7.0	6.0	5.2	4.6
10	3.7	2.8	2.3	2.0	1.7	1.5
12	1.6	1.2	1.0	0.85	0.74	0.65
14	0.72	0.55	0.46	0.39	0.34	0.30
16	0.38	0.29	0.24	0.21	0.18	0.15
18	0.21	0.16	0.13	0.11	0.10	0.09
20	0.13	0.10	0.08	0.07	0.06	0.05
24	0.052	0.04	0.03	0.03	0.02	0.02
30	0.017	0.013	0.011	0.009	0.008	0.007

Example:  $k$  for 12" pipe, 4000 ft. long,  $C=100$ , is  $1.2 \times 4.0 = 4.8$

Fig. 4A. Application of Hardy Cross Method—Nomograph for Values of  $1.85kQ^{0.85}$  and  $kQ^{1.85}$

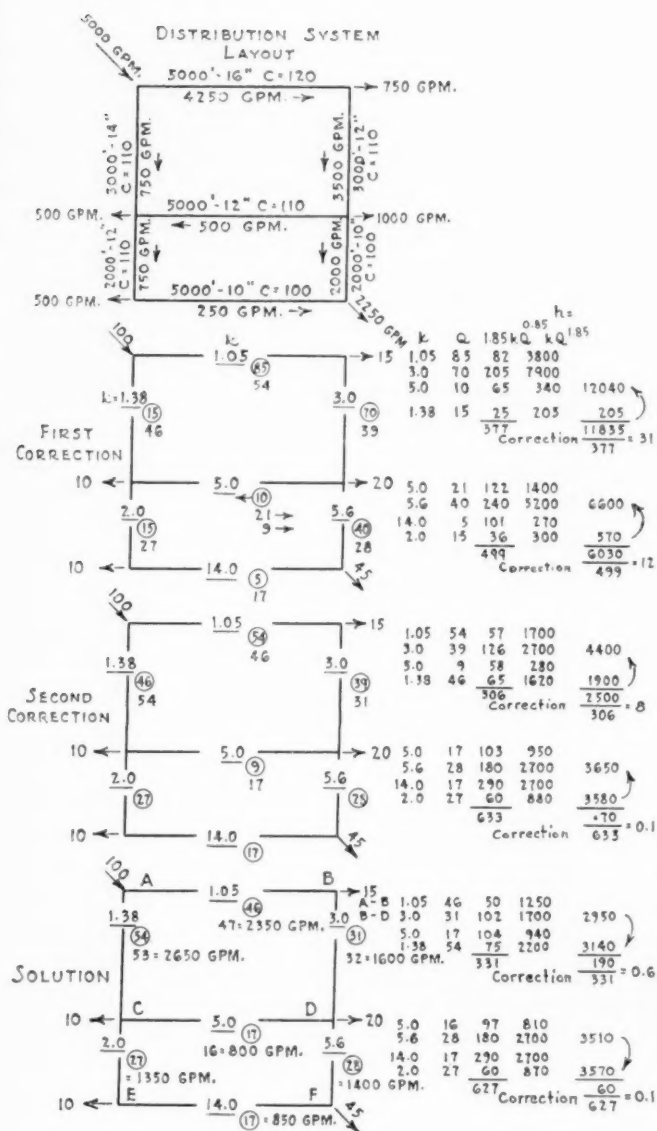


FIG. 4B. Application of Hardy Cross Method—Worksheet

## OUTLINE OF PROCEDURE

1. Assume any flow distribution.
2. Replace the size, length and roughness of pipe by the coefficient  $k$ .
3. Show  $Q$  in per cent of total flow.
4. With the aid of the chart compute in each pipe the loss of head  $h = kQ^{1.85}$ . With due attention to sign (direction of potential drop) compute the total head loss around each elementary closed circuit  $\sum h = \sum kQ^{1.85}$ .
5. Compute also in each such closed circuit the sum of the quantities  $1.85 kQ^{0.85}$  without reference to sign.
6. Set up in each circuit a counter balancing flow to balance the head in the circuit calculated by the formula  $\sum kQ^{1.85}$ .
7. Place the corrected flow on a new diagram  $\sum 1.85 kQ^{0.85}$  and repeat the procedure until the head loss, for clockwise and counter-clockwise flows, is balanced within any desired limit of error.
8. The loss of head between any two points may be calculated by multiplying the sum of the  $h$  values between the points by  $(0.01 \text{ total flow in g.p.m.})^{1.85}$  divided by 100,000

WILLIAMS-HAZEN FORMULA CONVERTED TO THE FORM  $h = kQ^{1.85}$

$$V = CR^{0.63} S^{0.54} \quad 0.001^{-0.04}$$

$$= C 1.31826 R^{0.63} S^{0.54}$$

$$= C 0.55043 D^{0.63} S^{0.54} \quad D \text{ in ft.}$$

$$= C 0.013204 D^{0.63} h^{0.54} \quad h \text{ in ft. per 1000 ft.}$$

$$= C 0.0027594 d^{0.63} h^{0.54} \quad d \text{ in inches}$$

$$Q = C 0.00001505 d^{2.63} h^{0.54}$$

$$h = \left( \frac{Q}{C 0.00001505 d^{2.63}} \right)^{1.85} \quad Q \text{ in cfs.}$$

$$= \left( \frac{148 \times Q}{C \times d^{2.63}} \right)^{1.85} \quad Q \text{ in (U.S.) gpm.}$$

$$= Q^{1.85} \times \left( \frac{148}{C \times d^{2.63}} \right)^{1.85}$$

$$\frac{h}{Q^{1.85}} = k_a = \frac{10357}{C^{1.85} d^{4.87}}$$

Example: Find  $k_a$  when  $d = 10''$  and  $C = 100$

$$k_a = \frac{10357}{100^{1.85} 10^{4.87}} = 0.00002788$$

FIG. 4C. Application of Hardy Cross Method—Outline of Method and Conversion of Williams-Hazen Formula

The friction formula used was the Williams-Hazen formula:  $V = CR^{0.63} S^{0.54} 0.001^{-0.04}$  owing to its wide application in distribution system design and to the fact that its application to the Hardy Cross method has been simplified by J. J. Doland (2). A value of  $C = 110$  was decided upon, as tuberculation is very slight in the Winnipeg area. As was stated previously, multiple mains were reduced to equivalent pipes; since these equivalent pipes were of ten fractional numbers, a graph (Fig. 5) was plotted to facilitate the determination of the value of  $k$ .

Having determined the quantity and location of the take-offs and having decided upon the method to be employed, the actual calculations and necessary flow corrections were made. For this work, a smaller basic skeleton plan was prepared. The feeder mains were laid out on a map with a scale of  $\frac{1}{2}$  mi. to 1 in. A piece of tracing paper was then laid over the map and the feeder mains traced, together with the rivers and

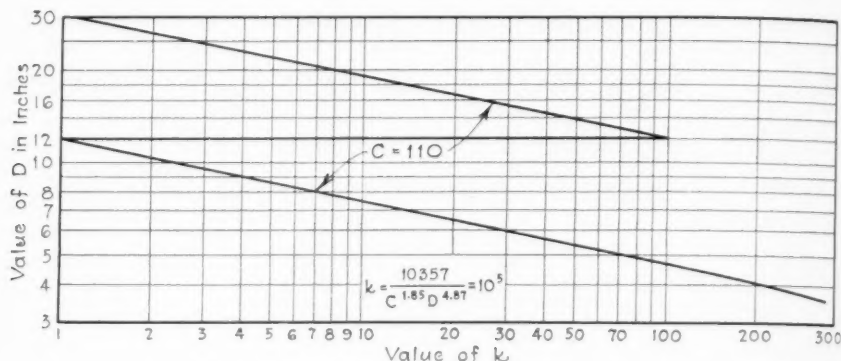


FIG. 5. Curve for Determination of Value of  $k$

boundaries of the city to give it orientation. White prints were then made from this tracing and used for working sheets.

On the first work sheet (Fig. 6), the take-off and the input from each pumping station, in percentage of total flow, were located. From Fig. 1, the lengths of the feeder mains were scaled. The unit values of  $k$  for each size of pipe were taken from Fig. 5 and the values of  $k$  for each length of pipe were calculated and marked on the appropriate feeder on the map. Each loop was lettered alphabetically. An initial assumed flow was then determined by distributing the flow from each pumping station to the primary feeders in ratio to the  $5/2$  power of their diameters.

The work of correction was begun, using Doland's simplification of the Hardy Cross method. Altogether seven corrections were made, giving results accurate to 0.1 per cent. Considering the assumptions that had been made, this was an unnecessary refinement and the number of correc-

tions could have been reduced. The existence of a separate feeder main contiguous to five loops was another factor in increasing the number of corrections, which could otherwise have been limited to four or at most five.

After the flow had been distributed, the loss of pressure in the feeder mains at all points of intersection was determined by using the factor  $h$  in psi. =  $0.172 \Sigma h$ , derived as follows:

$$\text{Total } Q = 36.7 \text{ mgd.}$$

$$\text{Reducing to (U.S.) gpm.,}$$

$$Q = \frac{36.7 \times 1.2}{24 \times 60} = 30,556 \text{ (U.S.) gpm.;}$$

therefore, the loss of head,

$$\begin{aligned} h &= \frac{\Sigma h}{100,000} \left( \frac{Q}{100} \right)^{1.85} \\ &= \frac{\Sigma h}{100,000} (305.56)^{1.85} \end{aligned}$$

$$\text{and therefore } h \text{ in ft.} = \Sigma h \times \frac{39,576}{100,000} = 0.39576 \Sigma h$$

$$\text{or } h \text{ in psi.} = \frac{0.39576}{2.31} \Sigma h = 0.172 \Sigma h$$

This was a relatively simple calculation. As already pointed out, the pressure at the McPhillips St. station is kept constant during the day at 75 psi. (in a main roughly 8 ft. below grade), while the pressure of the James Ave. station is adjustable only to a limited degree, and under peak conditions with full flow the pressure tends to drop well below 75 psi. At the peak load under consideration, the discharge was 5.7 mil.gal. at a pressure of just over 50 psi.

After the final correction was made on the third work sheet, another, on which the percentage of total flow and the  $\Sigma h$  were plotted for each section of feeder main, was made. By taking this  $\Sigma h$  value from the work sheet and multiplying it by the factor 0.172, the loss of head for that particular length of main was obtained. Starting at the McPhillips St. station and working outward, the pressure of the water in the mains was determined at all intersection points. By starting at one station and working to the other, and then comparing the calculated discharge pressure of the second station with the actual discharge pressure, a check on calculations was provided. The pressures obtained were the pressures of



FIG. 6. Worksheet on Hardy Cross Analysis of Winnipeg Distribution System

the water in the mains. As all mains are laid to a depth of 8 ft., as nearly as possible, and since the city as a whole is practically flat, no corrections were made for differences of elevation.

### Study of System From Pressure Contour Maps

Having obtained the pressure at various points throughout the city, it was a simple matter to plot a pressure contour map. The pressure drop in a main was considered uniform between two take-off points, a not unreasonable assumption. On the same map the flow in gallons per day was also plotted for each section of feeder main.

A study of the system made from the contour map confirmed certain known weaknesses and revealed other conditions which had not been apparent. In other words, the map gave a graphic picture of the system, its strength and its weaknesses.

It was known that the pressure near the southwest city limits on both sides of the Assiniboine river was low under peak flow conditions. From the map it was at once obvious how sharply the pressure fell, due chiefly to inadequate mains.

It had been known, too, that the pumping capacity at James Ave. was inadequate, but how inadequate this was, particularly under peak conditions, was shown graphically by the fact that the water contributed by this station was used up within a few blocks after entering the downtown area.

The map showed that, with the exception of auxiliary supply, two of the ten river mains, under peak loads, were of little use as feeders, since the amount of water flowing in them was almost negligible compared to their potential capacity. It was demonstrated, too, that due to the method and location of the 18-inch special feeder, a good deal of water it carried recrossed the river through two other mains nearby, before entering the distribution system proper.

It might be stated that a pressure contour map could have been made of the existing system without recourse to the Hardy Cross method of analysis, by using recording pressure gages, but such a project would require a considerable amount of equipment and time. More important, however, is the fact that a contour map in itself reveals only existing pressure conditions and does not show flow conditions nor enable one to study and compare improvements or extensions of the system. It is this faculty of the Hardy Cross method which enables the engineer to study and compare different schemes of improvements and extensions of both existing and proposed systems, which, in the authors' opinion, is its most important advantage and one that has not been stressed sufficiently in the literature.



The Hardy Cross method could be applied to this portion of the system as it had been applied to the system as a whole. Of the original twenty-one loops, however, only four were used in these calculations. While it was true that any change in the flow conditions in these loops would affect the flow in the contiguous loops, it could be assumed that the amount of error arising by not considering the adjoining loops would be very small and, for all practical purposes, could safely be neglected in a comparative study of this kind. This assumption was later verified when the flow distribution of the whole system was checked after a number of new mains had been constructed. As it was considered likely that any scheme of improvements would not be constructed at one time, but would be done in stages, the study of each scheme was divided into sections corresponding to proposed construction.

With the aid of the Shand Nomograph, Fig. 4A, the calculations were made relatively quickly. These data showed clearly what improvements in pressure and flow conditions could be expected from each section of both schemes. Cost estimates were then drawn up for the proposed construction, and, after comparing the estimated costs of each scheme with the benefits to be derived from it, it was relatively easy to decide upon the most desirable and economical project.

Based on the results of this investigation, a substantial program of water main construction, during which over six miles of mains were laid, was initiated in the summer of 1939. Other mains were proposed for future construction and it was decided to increase the pumping capacity of the James Ave. station. This work is at present being carried out.

When the construction work had been completed, at the end of 1939, it was decided to revise the flow distribution analysis. The revised system of feeder mains was plotted on a work sheet, the number of loops being increased to 25. Five corrections were more than sufficient to balance the flow. Another pressure contour map, Fig. 7, was then plotted by the same procedure as used in the first and again using a pumping rate of 36.7 mgd.

As the average maximum hourly pumping rate in summer is 25 mgd., it was decided to construct a contour map for this rate of flow. This was accomplished by the determination of a factor to be applied to  $\Sigma h$  to obtain the pressure at any point in the grid for the lower rate, as follows:

$$\text{Total } Q = 25.0 \text{ mgd.},$$

$$\text{reducing to (U.S.) gpm.:}$$

$$Q = \frac{25.0 \times 1.2}{24 \times 60} = 20,833 \text{ (U.S.) gpm.};$$

therefore, the loss of head,

$$h = \frac{\Sigma h}{100,000} \left( \frac{20,833}{100} \right)^{1.85}$$

$$= \frac{\Sigma h}{100,000} \times 19,484.5$$

and therefore,  $h$  in ft. =  $0.195 \Sigma h$

$$\text{or } h \text{ in psi.} = \frac{.195}{2.31} \Sigma h = 0.085 \Sigma h$$

Since the pressure of all intersection points had already been determined in plotting the contour map for a flow of 36.7 mgd. (Fig. 6), the pressure at these same intersection points for a pumping rate of 25.0 mgd. could be obtained directly by using the factor developed below:

Let  $y$  be the pressure in psi. at any point,

$$\text{then } y_{36.7} = 75 - 0.172 \Sigma h \dots \dots \dots (1)$$

$$\text{and } y_{25.0} = 75 - 0.085 \Sigma h \dots \dots \dots (2)$$

Multiplying (2)  $\times 2.0344$ , we get

$$2.0344 y_{25.0} = 152.5 - 0.172 \Sigma h \dots \dots \dots (3)$$

Subtracting (1) from (3) to cancel  $0.172 \Sigma h$

$$2.0344 y_{25.0} - y_{36.7} = 77.5.$$

$$\text{Therefore } y_{25.0} = \frac{77.5 + y_{36.7}}{2.0344}$$

$$= \frac{77.5}{2.0344} + \frac{y_{36.7}}{2.0344}$$

$$= 38.1 + 0.492 y_{36.7}$$

By multiplying the pressure at any point for a flow of 36.7 mgd. by 0.492 and adding 38.1, then, the pressure at that point for a flow of 25.0 mgd. is obtained. From this the contour map, Fig. 8, was plotted.

In a similar fashion, without very much work, a contour map for any desired pumping rate could have been plotted. One thing, however, should be pointed out—that these secondary contour maps would be as accurate as the primary one only if two conditions remain fixed: (1) if the same percentage of water were pumped into the system at each pumping

station; and (2) if the location and percentage of take-offs were the same as in the case originally considered.

In this particular case, since by far the largest proportion of water was used by domestic consumers, it could safely be considered that the location and proportion of take-offs remained the same, but the ratio of water pumped by each station did vary slightly, i.e., since the pumping capacity at James Ave. is fully used, the proportion of water it contributes to the

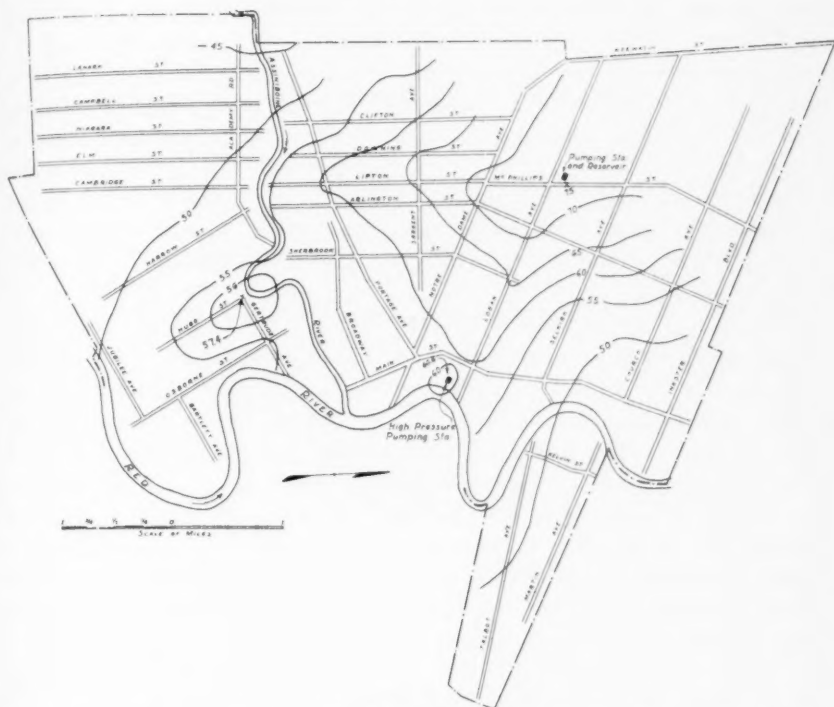


FIG. 8. Water Pressure Contour Map of Winnipeg Distribution System; for 25 mgd. rate of flow

system will be smaller under peak loads than under average conditions. This difference, however, would be comparatively small and in any case the actual pressure would be greater than the calculated pressure.

### Fire Protection

The question of fire protection, which is important to all communities, did not cause any major problems in this study. The reservoir and pumping capacity of the system is ample and in general meets the requirements

of the underwriters. A separate high pressure pumping and distribution system, with a capacity of 13,000 (U.S.) gpm. at 300 psi., protects the central business and commercial district, which includes nearly all of the heavily built up and high value property of the city. The remainder of the city, outside of the area served by the high pressure system is almost entirely residential and relatively free from congestion. Buildings occupy only from 25 to 33 per cent of the areas of the lots. These areas are also served by alleys and wide boulevard tree-lined streets. For residential areas like these, the underwriters require 500 (U.S.) gpm. or 600,000 gpd. This represents only 1.63 per cent of the maximum hourly flow. From observation it was evident that this fire flow would not affect the feeder system as a whole to any great extent. The feeders in the immediate vicinity of any fire would be affected a little more. Any large losses in pressure which might occur would be due to losses in the terminal mains from which the hydrants are fed. Since the Winnipeg system is a full grid system, made up of feeder mains interlaced with 6- and 8-inch laterals running in both directions, the losses are kept to a minimum.

#### Theoretical vs. Field Results

It was considered advisable to check the calculated results with actual conditions in the field. To perform this check, five recording pressure gages were installed at selected points in the field and a number of days' readings taken. The readings of two typical days are shown in Table 5.

The results indicate a fairly close check except in the case of Redwood and Main. This location was probably unfortunately chosen, as a large brewery is located at this intersection and wide variations in pressure occur there, depending on the demand. In all likelihood the brewery would not be operating at 7 P.M., so that the actual pressure would be higher than the calculated, as is indicated.

#### Conclusions

The Hardy Cross method is an effective tool with which the designing engineer can solve many of the problems of water main distribution systems. The study of Winnipeg's distribution system as outlined in this paper gives a good indication of the real value of analysis by this method. Once a study of a system has been made and pressure contour maps prepared, a graphic picture of the system and its weaknesses is available. Contours can be compared with those of a theoretically perfect system, i.e., a series of concentric circles with the pumping station at the center. Detailed studies on the correction, reinforcement and extension of distribution systems may readily be made.

Prior to the inception of this method it was impossible to design, with any degree of accuracy, facilities for an increase of supply to any particular point in a grid system. Good judgment based on experience was the only basis of procedure. With the Hardy Cross method, however, a system can be designed or analyzed accurately and quickly as described.

A complete analysis forms a basis, too, for solving quickly such special problems as the determination of drop in pressure due to the increased consumption in areas of a distribution system network where there has been an increase in population. Also, where a new residential area is

TABLE 5

*Comparison of Theoretical and Field Results on Typical Main Intersections*

NO.	LOCATION OF GAGE	PRESSURES IN PSI. AT:			
		Design Flow 36.7 mgd.	Flow at 7 P.M. July 22, 1940 38.1 mgd.	Design Flow 25.0 mgd.	Flow at 7 P.M. July 8, 1940 25.3 mgd.
1	City Limits Kenaston Blvd. at Academy Rd.	16.6	25	47.8	50
2	City Limits St. James St. at Sargent Ave.	30.1	33.5	54.4	57
3	Redwood Ave. at Main St.	26.1	41	52.4	63
4	Wellington Crescent at Hugo St.	42.1	37	60.4	60
5	Clare St. at Fisher Ave.	34.0	29	56.4	55

built adjacent to the distribution network, it is a simple matter to determine drops in pressure from increased consumption in those feeders extended into the newly developed area, so that the proper sizes of additional feeders can be provided. The same reasoning applies also to new industries requiring large quantities of water and the provision of ample fire protection.

From the foregoing it may be seen that, while a large amount of work is entailed in the initial analysis, it forms the basis of solving rapidly the design problems resulting from extensions or betterments of the system. Much has been written on the question of simplification of the Hardy

Cross method, particularly with reference to whether the quantity  $Q^{1.85}$  or  $Q^2$  should be used, and whether the equation:  $\Delta Q = \frac{\Sigma k Q^n}{\Sigma n k Q^{n-1}}$  (Doland's type) or  $\Delta Q = \frac{\Sigma h}{n \Sigma h}$  (Fair's type) should be employed.

If the Shand nomograph is used, the authors believe that any objection to the use of  $Q^{1.85}$  is completely overcome and, as a table or graph of the values of  $k$  is available, it seems that there is little or no advantage to be gained by using one type in preference to the other. The authors prefer Doland's type simply because they are accustomed to using it.

The merits of using  $Q$ , the quantity of flow, as a percentage of total flow, as against stating it in terms of actual flow in gallons per minute, has also been the subject of considerable discussion. It is believed that the use of "percentage of total flow" has certain definite advantages, particularly flexibility. If the flow is stated in percentage of total flow, simpler numbers are involved and the calculations and corrections are made more easily. Since most of the work has, as one object, the making of pressure contour maps for the purpose of correcting the weaknesses in a distribution system (usually revealed by low pressure), it is not always necessary to have the flow stated in actual units.

There has also been some discussion on the amount of time required to work out an analysis of a distribution network. This method of analysis is a tool, and, not unlike most tools, it usually takes more time to learn how to use it than it requires to perform certain mechanical operations once its use has been mastered. An engineer who is unfamiliar with the method will find that it will take considerable time to learn its employment. The actual amount of work involved will vary with the complexity of the problem and with the degree of accuracy required in the solution.

The distribution network is a relatively expensive part of any water supply system, estimated, depending on the size of the community, to represent from 40 to 70 per cent of the total cost of the entire system. It is evident, therefore, that a considerable amount of work and expense is justified to enable the work of design to be placed on a rational basis.

It is not out of place at this point to repeat that the actual accuracy of any specific problem depends on the proper selection of the take-off points and the accurate calculation of the draw at these points. This phase of the problem has not, in the authors' opinion, been sufficiently emphasized in the literature.

The writers wish to acknowledge the assistance of W. P. Brereton, City Engineer, in the work carried out, and for permission to present the results

of the work, and of Harold Shand, Engineer, Greater Winnipeg Water District, for helpful suggestions and for permission to use the nomograph developed by him.

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## Repairing Water Mains in Milwaukee

*By Reinhold H. Klebenow*

**T**HE Distribution Division of the Milwaukee Water Works maintains a 24-hour service to insure immediate and effective action toward the prevention of damage or inadequate service as a result of a break in a water main. While the repair of such breaks is more or less standardized as far as methods are concerned, the procedure followed by different water departments may vary considerably. As a matter of fact, the procedure followed by the Milwaukee Water Works is influenced by the time at which the break is reported.

The regular work week of the Distribution Division is five days, Monday through Friday, from 8:00 A.M. to 5:00 P.M. Any reports of breaks in mains during those hours are usually responded to by a three-man crew, which is held responsible for all necessary operations until the water main is shut off. An effort is made to contact and notify all consumers in the shut-off area, either verbally or, preferably, by a printed notice, of the time during which the shut-down will occur. Where individual consumers voice opposition to the proposed interruption in water service, an attempt is made to set a compromise hour, providing the break is under control, or to supply temporary water service to the premises through a hose line from a nearby hydrant. A recent shut-off necessitated by the failure of the stuffing box bolts in a 6-inch branch gate which was being operated, required the use of 3,600 ft. of 2½-inch fire hose to supply water to three consumers.

A common labor service crew of four men, including a compressor operator and truck driver, is also on duty during the regular work week from 4:00 P.M. to 12:00 M. This crew responds to emergency jobs reported after regular hours, or completes unfinished work in the field. Its work during the winter months, in hauling away excavated ground before it becomes frozen and backfilling trenches to protect underground distribution structures, offers the advantage of reducing the cost of jobs as well as hastening their completion.

A paper presented on October 8, 1941, at the Wisconsin Section Meeting, Racine, Wis., by R. H. Klebenow, Supt. of Distr., Milwaukee Water Works, Milwaukee.

After regular working hours, and during nights, Sundays and holidays, two men on eight-hour shifts are stationed at the Distribution Division office until 8:00 A.M. of the next regular work day. Their duties include the investigation of emergency calls requiring immediate action, such as breaks in mains, branches, services or hydrants, leaks and clogged or leaking water meters. These men have access to the distribution system maps and records of locations of mains, gate valves, hydrants and branches. A calking gang repair crew of three men and a common labor service crew of four men are available at all times if additional help is required in the event of a breakdown. Schedules are posted giving the names and addresses of these crews, which are rotated so that each crew is subject to call for every sixth overtime job.

### Maintenance of Services and Mains

In July 1936, the Common Council of the City of Milwaukee adopted a resolution transferring the maintenance of the service pipe between the water main and the curb stop from the property owner to the water department. On service lines where the control gate valve is near the main, a fixed point, 1 ft. in back of the curb, has been established as the division line for repairs. These services are maintained by the Distribution Division.

During the past winter, eight cast-iron branch pipes broke at the curb wall of the hollow sidewalk area in the immediate downtown section of the city. These breaks occurred at the beginning of cold waves and, in addition to causing inconvenience, resulted in the flooding of basements and other damage before leak indications were observed. Sub-zero weather also added to the obstacles and time required to answer the calls and close the gate valve controls in the street. These branch pipes were installed by private plumbers and built solidly into the wall, with no provision for movement of either wall or pipe. The division, in repairing these breaks, inserted a cast-iron sleeve in the wall which provided an annular space of not less than 3 in. between the outside of the water pipe and the inside of the sleeve. This space was filled with an 85/100 penetration asphalt, which provides the necessary cushion for any reasonable underground disturbances.

The distribution system, as of January 1, 1941, included approximately 1,000 mi. of mains, ranging in diameter from 4 to 54 in. Breaks in mains from 4 to 16 in. in size average about twenty per year, and failures due to corrosion or electrolysis in mains 4 to 12 in. in size, about nine per year. Such breaks usually result when nearby excavations disturb the firmness of the bed and cause shifting; when other structures are built near or over the main; from settlement; and from improper backfilling or poor construction.

Experience has proved that breaks in mains usually occur at sudden and abrupt drops in temperature.

The number of leaky joints repaired by the division, in mains of all sizes, average about 180 per year. The largest percentage of joints are recalked entirely. Lead joints which do not meet a satisfactory test are melted out and re-run if the main can be drained at a point beyond the joint. To replace lead joints in a main which cannot be drained sufficiently through a blow-off or hydrant, a section of the pipe is cut out, the bell is split to remove the joint, and a new piece of pipe is sleeved in. This method of repair is applied only to mains varying in size from 4 to 16 in. in size. Repairs to compound joints are made in a similar manner, except that the old joint is chipped instead of melted out. The lead joints removed reveal that the most common causes of failure are low pouring temperature of lead, intermission in pouring, irregular depth of lead, improper calking, and wearing away of the cast iron in the bell or spigot by the leak. During the summer months the number of leaks increase directly with the water consumption, beginning during latter part of June and continuing into the early part of September.



## Practical Application of Ammonia-Induced Break-Point Chlorination

*By Clyde R. Harvill, J. H. Morgan and H. L. Mauzy*

IN RECENT years considerable interest has been manifested in treatment practices designed to maintain water of high quality in distribution systems. More attention is being given to the significance, in the system, of "after-growths," total plate counts and spore formers as indices of non-pathogenic contamination and to control of these factors by maintenance of a chlorine residual throughout the system. This practice is advisable in addition to, but not as a substitute for, an active program toward the location and elimination of all cross-connections in distribution systems.

The practical application of these policies involves alteration of accepted chlorination practice to guarantee thorough chlorination of all chlorine-reacting materials appearing in water supply and distribution systems. Experience indicates that, to assure completion of all chlorination reactions, chlorine must be applied at rates in excess of usual dosage rates for a considerable period of time, followed by de-chlorination to as high a residual concentration as can be maintained without creation of objectionable tastes and odors in the system. With complete reaction or oxidation of all chlorine-reacting materials, the resulting residual, after partial de-chlorination, should be quite stable and persistent since there is no further demand to reduce the residual unless such a demand is created by organic material in the distribution system.

For more than twelve years, the personnel of the Sanitation Section of the Houston Water Department has endeavored to control water quality deterioration and the occurrence of tastes and odors in the distribution system by application of modern treatment practices. Since the institution of chlorination at Houston in 1929, the change to chloramination in 1933, and the installation of automatic chlorination equipment in 1939, every effort has been expended toward improving the results of treatment

A contribution by Clyde R. Harvill, San. Engr., J. H. Morgan, Sr. Asst. San. Engr., and H. L. Mauzy, Asst. San. Engr., all of the Houston Water Dept., Houston, Tex.

practices in accordance with technical advances. Despite these endeavors, areas of poor circulation, dead ends, and "surge-point" areas have continued to develop stagnant and sulfurous odors and brown and black discolorations. Bacteriological examinations in these areas have established the existence of after-growths. The surge-point areas are created by the peculiar arrangement of Houston's water system, in which six plants, each with its own battery of deep artesian wells and a reservoir, discharge by booster pump to a wheel pattern grid system, with one plant occupying the hub position and the other five scattered in rim positions. Water consumption is such that the hub plant and one or more of the others cease operation during the night hours with consequent reversals of flow. These areas develop sufficient hydrogen sulfide to discolor silverware in less than a week, despite the fact that the sulfate content of Houston water is practically zero.

### Investigation of After-Growths

A short time after automatic chlorination equipment was installed, it was determined that certain hydraulic actuated units were fouling with organic growths at such rates and to such an extent that dependable continuous operation of the equipment was practically impossible. These growths were thriving in the presence of a 0.7 ppm. chloramine residual, by ortho-tolidine test, in the make-up water. Efforts toward securing dependability in equipment operation indicated that these organic growths were probably linked with the taste and odor problem and that the growths might be classified under the general grouping of "crenoform." Available information indicated that organisms of such characteristics may be present and protected in zones of "bio-fouling" (slime deposits) in such a manner as to survive in the presence of 1.0 ppm. residual chlorine, by ortho-tolidine test, for periods of more than one hour.

At the time that this phase of the investigations was initiated, plant treatment consisted of adding approximately 0.9 ppm. chlorine in the suction line from the reservoir to the booster pumps, followed, a few seconds later, by sufficient ammonia to yield a chloramine residual of 0.7 ppm. The stability and persistency of this chloramine residual in the distribution system varied considerably, not only from one plant to another, but from day to day.

### Required Chlorine Dosage Rates

Laboratory investigation of the effect of chlorine dosage rates necessary to secure the residuals required for control of crenoform disclosed that Houston's deep artesian well supply has a low chlorine demand and, at high dosages and residuals, develops a chlorine by-product taste and odor of a character similar to that termed "chlorophenol."

For the production of a palatable water with the high chlorine dosage rates necessary for control of crenoform, it was necessary to develop some type of treatment that would eliminate the tastes and odors created by the high residuals, either by de-chlorinating the residuals or by destroying the tastes and odors. Investigation revealed that both de-chlorination and destruction of the by-product tastes and odors can be satisfactorily accomplished by addition of a proper quantity of ammonia to the chlorinated water.

The shapes of the reaction curves obtained in the cases where chlorine only is added and where various chlorine dosages are treated with a definite

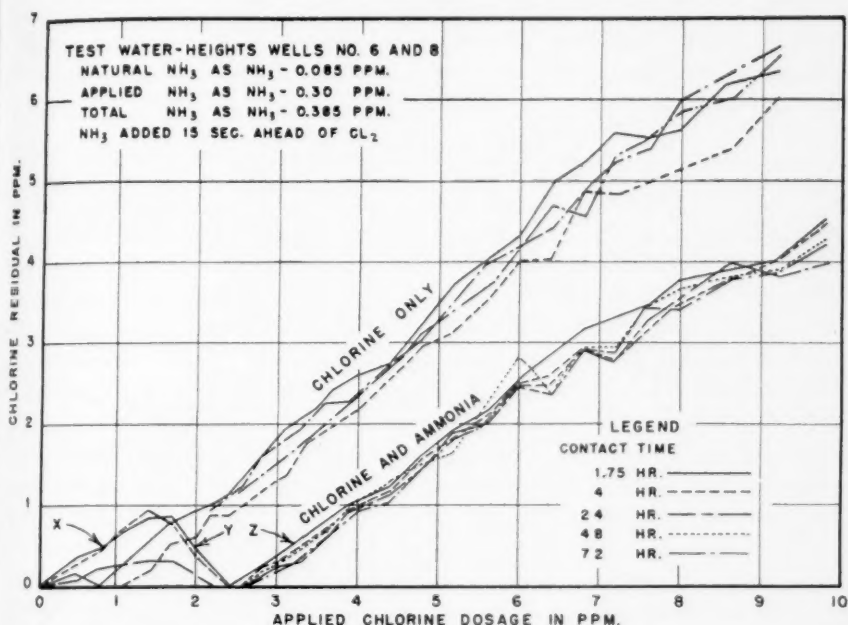


Fig. 1. Ammonia-Induced Break-Point; showing persistency of chlorine residual beyond break-point

quantity of ammonia are shown in Fig. 1. The obvious break-point curve that is obtained upon the addition of the ammonia reveals three phases:

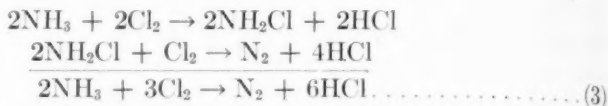
1. From zero dosage to the hump, chloramines are apparently being formed as in the equation:



2. From the hump to the break, a de-chlorinating action is apparently taking place, possibly in accordance with the equation:

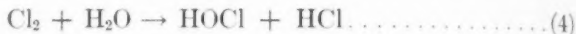


Thus, at the break-point, the end reaction, that amounts to complete de-chlorination and complete oxidation of the ammonia, has taken place as described by the sum of these equations:



A definite time interval is required for this last reaction to reach completion. In the laboratory experiments, with water of pH 7.7 at 85°F. in diffused natural light, 15 to 20 min. were required for completion.

3. Beyond the break-point, the ammonia apparently having been completely oxidized and the by-product tastes and odors having been destroyed, a free chlorine residual results, as shown by the equation assumed to represent simple water chlorination:



In all experimental work, the neutral starch-iodide method of measurement has been used. It was found that, for high residuals and for break-point chlorination work, the acid ortho-tolidine method gave false results. This was apparently due to release, by the acid in the ortho-tolidine, of chlorine that has reacted with chlorine demand components, in which form it is unavailable for sterilization. An attempt was made to develop an ortho-tolidine reagent with a lower acid content that would avoid the release of the so called "half-bound" chlorine, but this was unsuccessful, since a slight change in pH of the ortho-tolidine causes extensive color changes, the colors developed being muddy blues or browns that make accurate differentiation difficult. Attempts to correlate the acid ortho-tolidine residual with those obtained with neutral starch-iodide were unsuccessful if the residual was to the left of the break-point. To the right of the break-point, however, where a straight chlorine residual exists, it has usually been possible to check results fairly closely up to 1.0 ppm., the range of the usual colorimeter slide. In measuring residuals for making calculations of necessary dosages or for location of break-points, however, the neutral starch-iodide measurement gives much more accurate and more reproducible results. It is a more logical method of measuring residual chlorine since it measures the chlorine available for sterilization at the pH at which the water is used, not at an artificial highly acid pH never encountered in a usable water.

In the work at Houston the ammonia-induced break-point always occurred at a ratio of 1 part of ammonia, as ammonia, to 6.25 parts of chlorine as indicated by Eq. 3. This is a definite chemical reaction and as such has definite constants that should not vary with the type of water employed. Recent articles in the literature have given ratios for this

induced break-point varying from 1 to 10 for buffered distilled water to 1 to 20 and 1 to 25 for natural waters. These ratios are based on ammonia, as nitrogen, and correspond to ratios of ammonia, as ammonia, to chlorine of 1 to 8.2, 1 to 16.4 and 1 to 20.6, respectively, as compared to the theoretical ratio of 1 to 6.25.

TABLE 1

*Effect of Total Ammonia Concentration on Location of Ammonia-Induced Break-Point*

AMMONIA DOSAGE AS PPM. $\text{NH}_3$			CHLORINE DOSAGE IN PPM. AT BREAK-POINT	
Natural	Applied	Total	Calculated	Actual
0.085	0.30	0.385	2.41	2.4
0.085	0.60	0.685	4.28	4.2
0.085	0.90	0.985	6.16	6.3

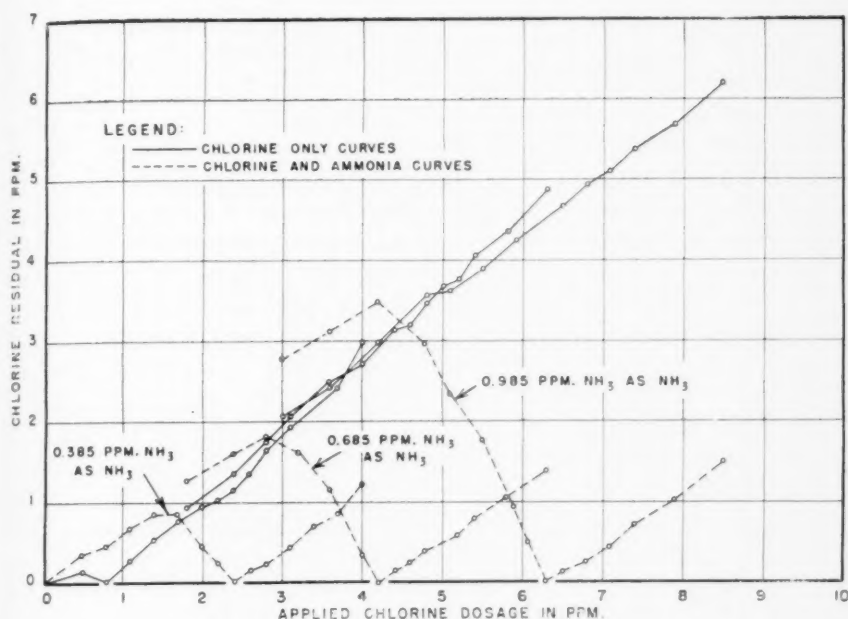


Fig. 2. Effect of Total Ammonia Concentration on Location of Ammonia-Induced Break-Points

### Effect of pH on Break-Point Location

Other recent articles have indicated that the pH of the test water affects the location of the induced break-point. Laboratory work in Houston has not confirmed these results. It has been found that the location of the induced break-point is a direct function of the *total* free ammonia present.

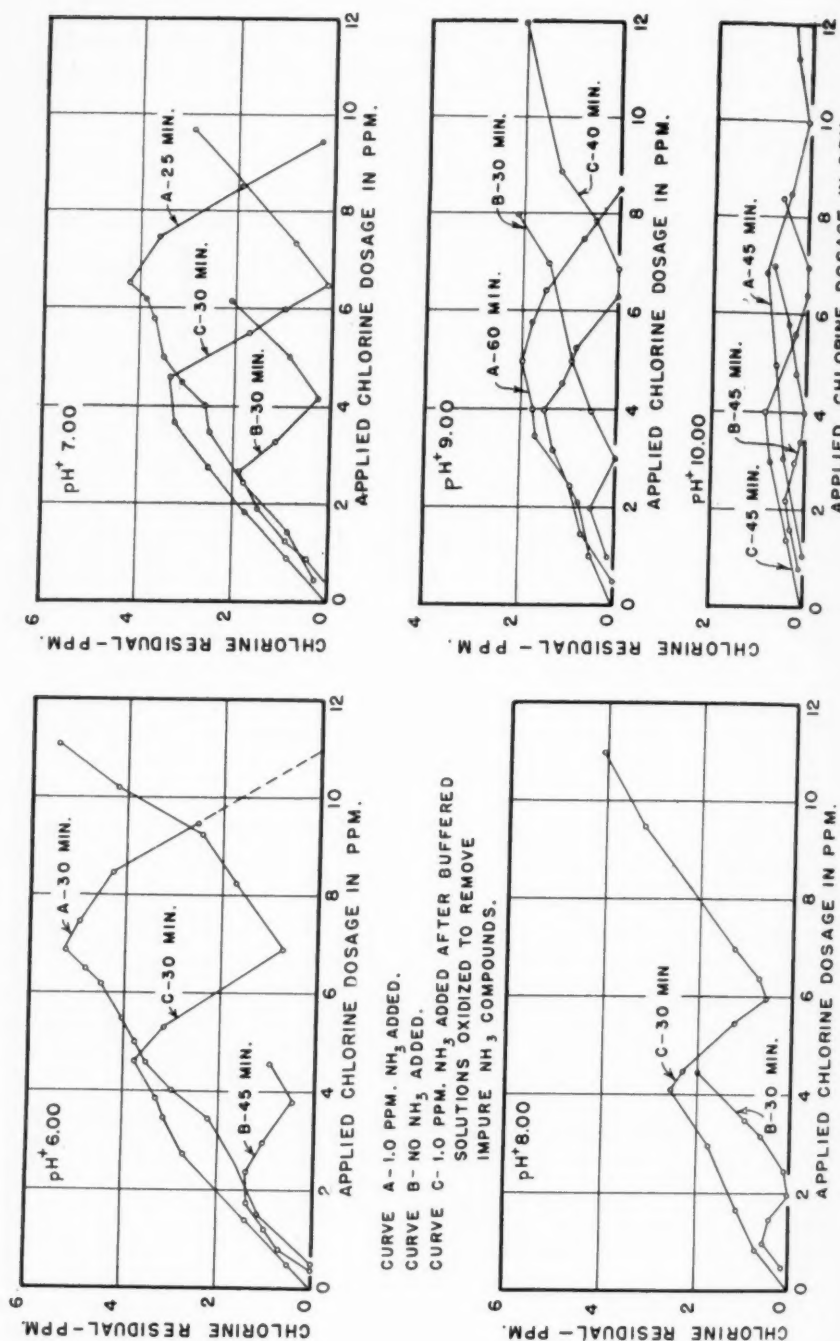


FIG. 3. Effect of Hydrogen Ion Concentration on Ammonia-Induced Chlorine Break-Points

The total free ammonia, i.e., the natural ammonia present plus the applied ammonia, *must* be used as a basis for calculations (see Table 1 and Fig. 2). When this is done, the experimental ratio will approximate the theoretical ratio of 1 to 6.25. Failure to consider the natural free ammonia undoubtedly accounts for at least some of the high ratios found for many natural waters. In waters from the Houston area in which natural break-points have been found, it is possible to shift the location of the break-point to the right by adding a known quantity of ammonia. The amount of this shift corresponds to the amount indicated by the 1 to 6.25 ratio. For example, in a test water showing a natural break-point at 2.0 ppm. chlorine dosage, the location of this break-point was shifted to 5.7 ppm. by the addition of 0.6 ppm. ammonia, as ammonia. This is a shift of 3.7 ppm. as compared with a calculated shift of  $0.6 \times 6.25 = 3.75$  ppm.

Further experiments have indicated that the pH of the water apparently has no effect on the location of the break-point. Waters of various buffered pH, made up in accordance with the procedure of *Standard Methods*\* and checked electrometrically, yielded the results given in Fig. 3. The three curves (A, B, and C, respectively) for each pH value represent results obtained (A) on addition of 1.0 ppm. ammonia to the buffered water, (B) on buffered water with no ammonia added, and (C) on addition of 1.0 ppm. ammonia to the buffered water *after* adding the amount of chlorine indicated by Curve B to remove impurities causing a natural break-point. It should be noted that at all pH values, after removing impurities, the ratio at the break-point approximated the theoretical ratio of 1 to 6.25.

In ammonia-induced break-point chlorination work, care must be taken to differentiate between *dosages* of chlorine and *residuals* of chlorine. In relatively pure waters, having a low initial chlorine demand, if the ammonia is added first, the chlorine *dosage* may be used to calculate the location of the break-point. Where an initial chlorine demand exists (hydrogen sulfide, for example), the amount of chlorine necessary to satisfy it must be taken into consideration before calculations are made. If the chlorine is added first, particularly when considerable time elapses before addition of the ammonia, the chlorine *residual* at the time of ammonia addition must be used as a basis for calculations. Under these conditions the natural ammonia may be ignored, since it has been oxidized by the chlorine, provided an excess of chlorine exists. This is the condition in the plant scale arrangement described below. In other words, it is the chlorine *available* for reaction with the ammonia that determines where the break-point occurs for a given quantity of ammonia. When all of the above factors are evaluated, the break-point will always occur at a ratio

\* *Standard Methods of Water Analysis*. Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936). p. 240.

1 to 6.25. This has been verified on several waters, both ground and surface, in the vicinity of Houston.

### Plant Scale Operation

Several months ago, the treatment procedure at one of the pumping plants (Heights Plant) was changed on the basis of the above information so that a chlorine dosage of 2.3 ppm. was applied ahead of a 50,000-gallon sand trap as shown on the flow sheet (Fig. 4). After 8 to 10 min. retention, the water had a residual of 1.4–1.6 ppm. as it flowed to a 750,000-gallon covered concrete reservoir with a retention of 2 to 3 hr., after which the residual was 1.2–1.4 ppm. At the pump suction, 1.2 lb. per mil. gal. (0.14 ppm.) ammonia was added, requiring 0.90 ppm. chlorine to oxidize it and leaving a free chlorine residual of 0.3 to 0.5 ppm. after completion of the reaction (15 to 20 min.). Due to the reaction time lag, the plant tap showed a residual of 1.0 to 1.2 ppm. but had no taste or odor.

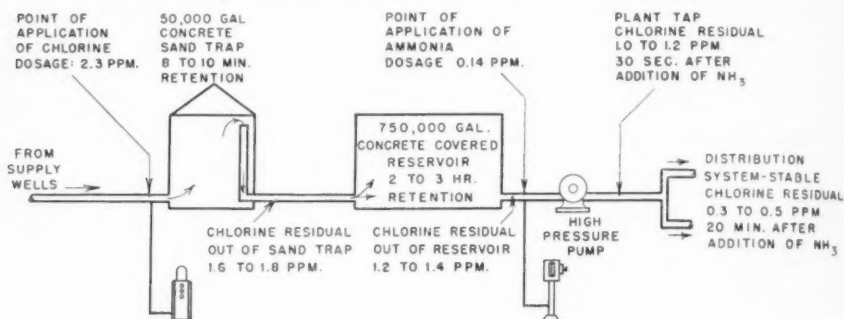


FIG. 4. Flow Sheet of Houston Heights Water Plant; showing points of application of chlorine and ammonia and chlorine residuals for ammonia-induced break-point chlorination

Before this treatment was initiated, the chloramine residual had dropped to zero only a few blocks from the plant. With it, the free chlorine residual was carried rapidly to all parts of the distribution system. As the water with this free chlorine residual moved through the mains, unprecedented chlorine by-product tastes and odors and red and yellow discoloration developed. This trouble was apparently caused by the reaction of the residual chlorine with the "bio-fouling" (slime deposits) in the system. As soon as this was flushed out, however, a clear, sparkling, tasteless and odorless water resulted. A stable residual is now maintained throughout the system, with the exception of the last few blocks of dead-end mains (Fig. 5).

The free chlorine residual at the plant is gradually being increased by lowering the ammonia dosage. At present 0.8 ppm. free chlorine residual

is being carried in the system without taste, odor or color. It is believed that this residual can steadily be increased to any desired reasonable value as the "bio-fouling" in the far ends of the system is gradually eliminated.

It should be stressed that ammonia-induced break-point treatment must be carefully controlled, since small variations in the ammonia dosage can alter considerably not only the quantity but even the type of residual. By proper selection of the ammonia dosage, either a chloramine or a free chlorine residual may be left in the water after de-chlorination. In Fig. 1, for example, the 0.5 ppm. residual at Point X is apparently a chloramine residual of retarded sterilizing ability. The 0.5 ppm. residual at Point Y

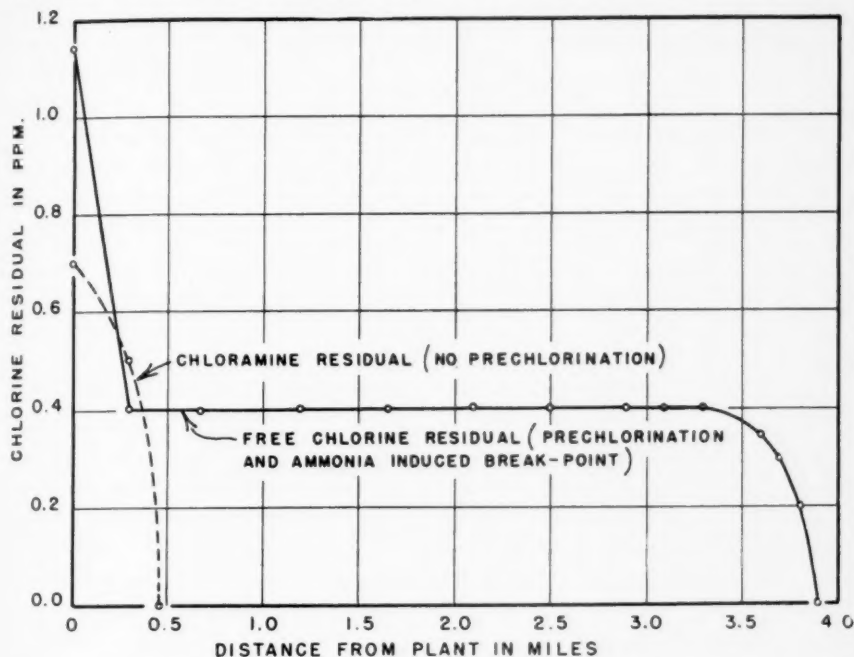


FIG. 5. Persistency of Free Chlorine and Chloramine Residuals in Houston Heights Water Plant Distribution System

is apparently still a chloramine residual, with possibly a greater sterilizing value than at Point X, since some of the ammonia has been completely oxidized. The 0.5 ppm. residual at Point Z is apparently a free chlorine residual of active and rapid sterilizing action.

The above variations in treatment can be used advantageously in systems where considerable organic material exists. The free chlorine residual would probably create excessive tastes and odors while the organic material was being eliminated, but after destruction of the organic material, a

clear, tasteless and odorless water would be obtained. On the other hand, the two chloramine residuals would probably not create taste and odors, but neither would accumulated organic material be eliminated. Similarly, by careful control of the ammonia dosage, complete de-chlorination can be accomplished so that no residual chlorine is left in the water. This might be desirable at plants supplying certain types of industries that require a sterile, yet chlorine-free water. The choice of type and quantity of residual is, of course, dependent on the system being supplied, but the important point is that with ammonia-induced break-point chlorination, after complete sterilization and oxidation has been accomplished, several types of residual in any quantity can be secured with standard equipment and chemicals.

### Summary

In Houston, a method of treatment was developed in which an artificial break-point is induced by the addition of ammonia to de-chlorinate the high residuals and to destroy the chlorine by-product tastes and odors resulting from super-chlorination. Super- and pre-chlorination are being used at all plants to control tastes and odors in the distribution system. By partial de-chlorination with the ammonia-induced break-point, high concentrations of residual chlorine can be maintained throughout the system.

Laboratory experimentation and plant scale operation indicate that this induced break-point always occurs at a ratio of 1 part of ammonia, as ammonia, to 6.25 parts of chlorine. At this ratio, complete de-chlorination and complete oxidation of the ammonia occur. Any excess of chlorine above that necessary for complete oxidation of the ammonia yields a stable persistent free chlorine residual.

If natural free ammonia is present, it must, of course, be considered in calculating the location of the break-point. Care must be taken also to avoid confusion between chlorine *dosages* and chlorine *residuals*. With proper evaluation of these items the experimental ratio will approximate the theoretical ratio of 1 to 6.25. Hydrogen ion concentration has no apparent effect on the ratio.

The neutral starch-iodide method of chlorine residual determination is recommended for ammonia-induced break-point chlorination work to avoid inaccurate results obtained with acid ortho-tolidine.

Plant scale operation of this treatment process has shown that, when Houston's water supply is partially de-chlorinated in this manner, the resulting free chlorine residual is very stable and persistent, even more persistent than chloramine residuals. It is possible to maintain free chlorine residuals of high value throughout the distribution system with no taste or odor whatsoever.

**Discussion by C. K. Calvert.\*** It is a pleasure to read the report of another case in which high rates of chlorine application have reduced taste and odor problems and where ammonia has been used to de-chlorinate the water before delivery into the distribution system. Most distribution systems contain slime bacteria which, directly or indirectly, consume chloramine residuals, so that it is interesting to learn that such small amounts of actual chlorine loosened these growths and that after they were gone the delivered water was sparkling clear and free from taste and odor. Where the water contains considerable organic matter these slime deposits are not so easily removed and some slime deposits resist even more residual chlorine than is reported by the authors.

The three points, X, Y and Z, shown in Fig. 1 are similar to those points investigated by Levine† with respect to the bacterial kill. He used spore-forming organisms for his test and found that only at the point corresponding to Z was the kill rapid, and that at X and Y the kills were very similar. The authors' assumption that part of the ammonia has been destroyed at Point Y may be substantiated by the determination of ammonia by direct Nesslerization, but after de-chlorination and distillation it has been found that the amounts of ammonia at Points X and Y are substantially the same. At both Points X and Y the chlorine present is united with the ammonia and, in this condition, is decidedly less active as a bactericidal agent than at Point Z.

In calculating the relationship between the ammonia and chlorine destroyed at the break-point the author uses the expression  $\text{NH}_3$ . An opportunity must not be missed to recommend that all nitrogen forms be expressed as N. If only the nitrogen as ammonia is to be considered in the reaction between chlorine and nitrogenous compounds, the expression  $\text{NH}_3$  might be justified, but there are other nitrogenous compounds which react with chlorine in a similar fashion. To keep the relationship on the same basis it would appear that the whole matter would be simplified by expressing all of the figures on the basis of nitrogen itself.

There have been reports of situations in which taste and odors were not destroyed in low ammonia waters by the application of considerable quantities of chlorine. These tastes and odors were destroyed, however, by the addition of a small amount of ammonia, prior to the application of chlorine, sufficient to reach the new or induced break-point. Induced break-point or an extended break-point produced by the addition of more ammonia than that naturally contained in the water has not resulted in the elimination of certain tastes and odors in some waters. This paper

\* Supt. of Purification, Indianapolis Water Co., Indianapolis.

† WEBER, GEORGE R., BENDER, RICHARD AND LEVINE, MAX. Effect of Ammonia on the Germicidal Efficiency of Chlorine in Neutral Solutions. Jour. A. W. W. A., 32: 1904 (1940).

does not show, and it would be very interesting to know, whether or not the same rates of application of chlorine, followed by de-chlorination by some means other than the use of ammonia, would be successful with respect to taste and odor. If this information could be made available, light would be thrown on the question of whether a compound of nitrogen and chlorine formed at the break-point is more reactive with taste- and odor-producing bodies than chlorine alone. This has been suspected for some time but has not been demonstrated experimentally.

The graphs accompanying the paper exhibit very narrow valleys or very sharp break-points. In some waters the valley is quite broad. Broad valleys have been produced experimentally by the use of amines. From this it is suspected that many natural waters contain amines along with ammonia. While amines do react with chlorine, the reaction is slower than with ammonia. When a water containing both ammonia and amines is treated with chlorine in an amount sufficient to destroy the ammonia and a small amount in excess, this excess amount of chlorine is lost after an extended time. In such a situation, residuals cannot be expected to persist far into the distribution system or to be available for the destruction of slime growth in the pipes. Results obtained in a distribution system through which rather nitrogen-free water is carried cannot be anticipated in a system through which water rich in organic matter is delivered.

### Methods of Determining Chlorine

Suitable methods for the determination of chlorine in break-point investigations and in actual plant operation are undergoing a critical study by a committee at this time. It is probable that no single method will meet the requirement of all situations. The reasoning presented in the paper in defense of the neutral starch-iodide method is good, yet it is not demonstrated that the acid-released chlorine has no germicidal value if the exposure time is long. In waters bearing organic matter the neutral starch-iodide titration is quite difficult because the end-point is not sharp. As a matter of fact, generally, the color of starch-iodide drifts back, especially before the break-point is reached. In titrating by this method, confusing results are frequently obtained. As a matter of fact, even a contact of 15 min. with the acidified iodide is insufficient in some waters to prevent a drift after the titration appears to be completed. It is more pronounced in waters exhibiting a wide valley at the break-point.

The ratio between the ammoniacal nitrogen and chlorine destroyed at the break-point, as given by the authors, is in complete agreement with results obtained when the residual ammoniacal nitrogen is determined by direct Nesslerization without de-chlorination. This appears not to be true when the ammoniacal nitrogen is determined by distillation prior to

Nesslerization and with de-chlorination preceding the distillation. Thus it would appear that methods of analysis need a considerable amount of attention and that they must be straightened out before far-reaching conclusions can be made.

The author's conclusion that the relationship between the ammonia and chlorine destroyed at break-point remains constant irrespective of pH seems hardly to be borne out by the results shown in Fig. 3. For instance, Line C which represents the results obtained with  $\text{NH}_3$  only, in the water shows the break-point to vary from 6.0 to 6.9 ppm. of applied chlorine. This would seem to be far from a demonstration of the stated conclusion.

In many of the experimental runs reported, the chlorine residual at the break-point is reduced to zero. This result cannot be expected in all waters, especially with such short contact periods, although the high temperatures at which the experiments were conducted would tend toward this result.

Waters are quite different with respect to the organic matter and to the various forms of nitrogen which they contain. On this account it is hazardous to make sweeping conclusions on the basis of work done on any particular water. Until methods for the estimation of free chlorine, chloramines, ammonia and various other forms of nitrogen are well in hand an explanation of the break-point phenomenon which will stand the test of time and further experience, is not likely to be made.



## ABSTRACTS OF WATER WORKS LITERATURE

**Key. 31:** 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.*—*Bulletin of Hygiene (British)*; *C. A.*—*Chemical Abstracts*; *P. H. E. A.*—*Public Health Engineering Abstracts*; *W. P. R.*—*Water Pollution Research (British)*; *I. M.*—*Institute of Metals (British)*.

### DEFENSE

**Some Engineering Aspects of A.R.P. in England.** H. A. BLAND. *J. Inst. Engrs. Australia.* **13:** 241 ('41). *Excerpts.*

"It is most important that professional men, and in particular engineers and architects, should be well and correctly informed on developments overseas in relation to A.R.P. [air raid precautions]. . . . The original shelter policy was based on the premise that the entire civilian population would take cover on the sounding of the alarm. Even civil defence workers were expected to take cover. The experts thought that raids would be of short duration and very heavy; that the sky would be darkened by masses of enemy bombers, all of which could not possibly be prevented from reaching their objectives. Plans were made accordingly.

"When the raids really started in earnest in July and August 1940, people were quite prepared to dive for the nearest shelter. Shops and offices were closed and surface transport stopped. If one was in the street, one usually made for a basement shelter or a surface shelter of which great numbers had been built. Chaos resulted! . . . All had taken shelter! Instead of being short and sharp, the raids lasted up to as much as twenty-one hours a day at one period. This did not leave much time for any work and, obviously, in the national interest could not be allowed to continue.

"The first move to alter the governmental attitude to civilians' taking shelter came from employees in industry. . . . Men selected by the workers from volunteers among themselves, were trained by the Royal Air Force in identifying planes, and on the sounding of the 'alert' would repair to the factory or office roof to keep look-out. Their protection was usually a pill-box type of erection permitting ample vision. . . . The risks of being killed or injured by bombs are these days accepted with the same nonchalance that the average Sydneian [resident of Sydney] accepts similar risks resulting from the presence of motor vehicles on roads. Traffic moves normally. The clerk in the city works at his desk—raid or no raid!

"Initially, the whole British shelter policy was based on the principle that the people should be able to reach shelter within seven minutes from the sounding of the alarm. This was the approximate time available between the giving of the warning to an area and the arrival there of the bombers. The new system of delaying warnings to the last moment made it necessary to shorten the time within which shelter could be reached. New shelters were sited within two minutes reach of factory personnel. This arrangement was facilitated because much had been learned from the fate of load-bearing brick walls under the influence

of bombing. Previously, shelters had been kept well away from walls for fear that their collapse might bring disaster to shelterers. But such walls did not fall outwards or inwards in large sections, instead they tended to collapse almost perpendicularly in very small fragments—sometimes there were few pieces of debris consisting of greater than a couple of joined bricks. It therefore was practicable to site shelters in much closer proximity to walls either inside or outside the premises.

"Some factories did not bother about constructing new shelters at all, but, instead, built reinforced concrete or brick walls, 6 ft. 6 in. or so high, to divide machines. The boxing-compartmenting result gave protection both to personnel and equipment from blast, splinters or fragments. Serious damage could, of course, occur in one compartment, but personnel and machinery in the adjoining compartment might suffer no injury whatever.

"I want particularly to stress the change in the people's attitude to bombing and their present indifference to day raids; in point of fact the risk of death from bombing was never great by comparison with the risks of unnatural death concomitant with ordinary everyday existence. In the first twelve months of aerial attack on Britain, the risk of death by bombing was only about six times greater than the risk of death resulting from motor traffic accidents.

"Sustained night raiding produced in the public, initially, much the same reaction, I imagine, as was experienced by those who served in the last war and underwent an artillery barrage for the first occasion. The people just grabbed any shelter that offered. Not unnaturally no steps had been taken in anticipation of shelters being required for use as dormitories, consequently there were no sleeping or hygienic arrangements. People slept on concrete floors on blankets, coats or any sort of covering—even American cloth or newspapers. Conditions were deplorable. Sanitary arrangements were non-existent or primitive in the extreme.

"In January 1941, only 44,000 sought shelter in the tubes. There were bunks,

excellent lavatories, book clubs, concert parties—all the amenities of the West End, but in spite of all these comforts, the tube population continued to decline. . . . The changing attitude was, to some extent, a process of self education, though there was Government stimulus in the way of adroit propaganda aiming at dispersal, shelter within the home, and sleeping in bed as normally.

"The Government had, of course, always favoured a policy of dispersal of the shelter population and its propaganda stressed the theme that there was less danger in sheltering in or at home than in the public shelter. Not only was the risk of a calamity avoided, but the chance of the rapid spread of epidemic diseases was considerably lessened. Unhappily for the theorists of mathematical tendencies, bombs have a quite inexplicable habit of obstinately failing to conform to pedagogic patterns and scientific formulae in relation to the distribution of their fall.

"In January 1941, on the occasion of one of the periodic nightly censuses of shelter population, it was found that only 5 per cent of the people in the London region were using public shelters, and that 19 per cent slept in domestic or communal shelters. The remaining 76 per cent slept in their beds; that is, if they were not on duty with one of the Civil Defence Services or taking a turn of roof-spotting or fire watching.

"The original shelter policy . . . was to provide shelter only to the extent necessary to prevent demoralisation of the civilian population and to avoid the impairment of the war effort. There were to be domestic shelters, e.g., the Anderson shelters, shelters in factories, etc., having more than 50 employees, and shelters for the floating population. For the latter, shelter was to be provided to the extent of 10 per cent of the population in residential areas and 15 per cent in business areas.

"Some exhaustive tests have been carried out in England on the behaviour of different types of shelters under assumed conditions. The inverted "U" type, specified in Circular 290/1940, placed cornerwise on, stood up very well to the explosion of a 500 lb. bomb at twelve feet.

There was a certain cracking, but the shelter did not disintegrate—there was no collapse and occupants would have been quite unharmed. I know of a case of such a shelter beside which, in a raid, bombs had dropped at 3 and 20 feet. The shelter had moved through 90° from its original position, and the people sheltering in it had sustained nothing more than bruises. An even better design was the reinforced concrete box type of shelter referred to in a memorandum (CE./G.E.N./48) by the Home Office Engineer, Sir Alexander Rouse. This type of shelter is erected on a base of sand or rubberoid, or other substance permitting movement of the whole structure. This same type of shelter is now used in England extensively for the protection of key men in factories who have to be at their posts right through a raid.

"For domestic shelters 'umbrella' and table type shelters were devised, being constructed or situated within a room of the dwelling, but independent of the original structure, and capable of supporting the debris load that might fall. The Morrison 'mouse trap' shelter was perhaps the most important contribution in this field; its dimensions are 6 ft. 6 in. x 4 ft. x 2 ft. 6 in. high. It is designed to be used as a table ordinarily and a shelter in emergency. It can be assembled by the householder according to simple directions. It has a steel roof or top, steel uprights, and side of steel wire mesh, and is capable of accommodating a man, his wife and a child. . . . The principal advantage of the Morrison 'mouse trap' is that it enables people to live in their own homes under reasonably comfortable conditions, so implementing the policy of dispersal. It avoids the necessity for leaving the warmth of the fireside for the bitter cold of an outdoor Anderson or a communal domestic or public shelter. The dive for shelter can be left to the last moment. Of course nothing is very much good against the unannounced land mine that may come floating down entirely without warning and convert, in the space of seconds, more than six dozen houses into neat heaps of rubble and splintered timbers.

"If I were asked to express an opinion on the relative safety of various types of

public shelters, I think I should rank them as follows: (1) *Properly protected basements* of steel framed or reinforced concrete buildings, provided they were suitably sub-divided with not more than fifty people per compartment. The chief danger with this type is from flooding or gassing by burst utilities, and care must therefore be observed to provide against this risk. (2) *Ground and upper floors* of similar types of buildings provided there be proper lateral protection and four floors of fire-resistant material above. (3) *Trench shelters* of the reinforced concrete box construction. The concrete should be poured *in situ*. Unfortunately such can usually be sited only in parks and their usefulness is therefore lessened. (4) *Reinforced Concrete Box Pillboxes* of the type described in Sir Alexander Rouse's circular previously mentioned. (5) *The Inverted "U"* of reinforced brick or concrete walls tied into a reinforced concrete roof (Circular 290 of 1940). (6) *Properly strengthened ground and basement floors* of individual shops and houses in a terrace protected in accordance with the Code.

"As for the domestic type, I would give the Morrison "mouse trap" first place. I say this, taking full account of the risks of suffocation under debris and of asphyxiation. Next place I would give to the indoor "umbrella" or table type of independent shelter construction. Its disadvantage chiefly is that it takes valuable timber, spoils the appearance of a room, and requires some skill in assembly. Of the outdoor domestic types the Anderson shelter is very excellent if properly sunk and covered and if there is no water problem, and provided, too, that such does not have to be used as a dormitory.

"*Deep Shelter*. A great deal has been said and written about deep shelters. Too often have the protagonists of deep shelters, ostrich-like, disregarded the fundamental realities of the needs of the situation and failed to take account of certain distinguishing features of British character. . . . The Government's refusal to construct deep shelters was based on certain obvious facts, chief of which were that the proportion of the people who could be accommodated in deep shelters

was small; the necessary labour could not be spared; the requisite materials were not available; construction was a lengthy process; and the cost per capita unduly high.

"Firm action had indeed to be taken in those early days or a serious situation from the morale point of view might have developed. Just such a situation did develop in one town in England. This relation of lowered morale to deep shelter is no myth. One series of inspections of cave shelters and their dwellers by Mr. Morrison shocked him and certainly confirmed for him the unwisdom of deep shelter policy. The Government had, shortly before these inspections, agreed to the construction by the London Passenger Transport Board of certain tubes in London for immediate use as deep shelters and ultimate inclusion in the Tube Railway system. It also agreed to consider other deep shelter schemes if little tunnelling were involved, little skilled labour required or materials needed, and the total cost per capita were not unduly high. Some such schemes have been submitted to the Government; but the few proceeded with have utilised existing facilities, such as disused railway tunnels, disused mining skipways and stormwater conduits, or natural phenomena, such as caves and underground passages.

"The London Passenger Transport Board's scheme provided for the housing of 100,000 people. If it is completed the cost will probable exceed £2,000,000, or approximately £20 per capita. I personally do not think it will be completed or that the sections finished will necessarily be used for shelter purposes.

"I expect few would disagree with the proposition that deep shelters, that is relatively safe shelters, *qua* shelters, should be reserved, if insufficient accommodation could be found for all, for the most valuable and important producers and key men in the realm, e.g., key machine tool makers. Let anyone ponder the difficulties confronting him who would intelligently apply this. I know that no solution of the problem of selection and discrimination had been found when I left London. Ponder also the

feelings of the Civil Defense workers toiling in the thick of the falling bombs if they knew that a large section of the population was sheltering in the deepest shelter removed or almost removed from any danger. This is total war affecting all civilians. Common danger must therefore be shared equally. So far as the London tubes are concerned, I have already referred to the remarkable and continued decline in the number sheltering therein.

"In the last week of December, 1940, London learned the bitter lesson that the destructive power of incendiary bombs may be greater than that of high explosives, unless adequate precautionary measures are taken in time. It was the recognition of this fact that led to compulsory roof-spotting for fire bombs and patrolling to combat them. Buildings, whether in the city or suburbs, had to be watched all the time—night and day, week days, Sundays and holidays. At first, service with the fire parties was voluntary, but recently compulsion was applied to all males between the ages of 18 and 60. More than four and a half million people were engaged in fire watching when I left; that was before compulsion was applied universally. Now perhaps there are 10 million people liable to do 48 hours of fire watching per month. Women may volunteer—and do!

"One cannot fight incendiary bombs and the fires they cause, from the safety of the shelter. Deep shelters breed a disinclination to emerge at least during a raid. And there did occur cases of unfortunate shelterers who were incinerated. What would it avail to emerge from a shelter after a raid with a whole skin but with no city to habitate? Since their men folk were fire watching, the wives either gave a helping hand or stood by to refresh them after each tour of duty with tea or something better. More and more forsook the shelter for the job on hand. The progress from the shelter, deep or otherwise, to the street or the roof tops reflected the British people's growing determination to preserve at all costs the nation's productive wealth and capacity, its cities and towns, even if the forfeit was loss of life or injury.

### Effect of Bombs on Buildings

"The effects of bombing on buildings are dependent on the type and size of bomb, the length of delay of the fuse, the height of release, the angle of impact and the type and construction of buildings affected.

"Apart from damage from impact and fire, the effects of high explosive bombs are due to three factors—blast, fragments, and shock. Damage done by bombs may be divided into primary and secondary damage. Primary damage is the direct result of impact and explosion of the bomb causing damage to structural elements and to non-structural elements, such as partitions, roofing materials, windows, doors, plaster, etc. Secondary effects are those resulting indirectly from primary effects and include the collapse of structures, where members have been destroyed by explosion or displaced by blast, or where falling debris has heavily over-loaded undamaged members.

"The effects of blast are governed to an extent by the confinement or obstruction of the blast wave. Plaster is stripped from ceilings and walls, windows and doors are blown from their fastenings, and light partition walls are destroyed. These things occur even when bombs fall outside the building. Whole window frames have been removed by blast and blown across a room to land on a bed with the glass panes unbroken. Fragments of broken glass constitute a serious danger to personnel and it is therefore most important for their protection that glass be removed or treated in such way that it will not splinter; this is done in many ways, e.g., by pasting butter muslin onto the glass, treating with cellular-like fabrics, and even by affixing strips of tough paper in criss-cross design. My own office windows were treated with fabric and though the glass was splintered into a thousand fragments, it continued to adhere to the fabric and the whole pane came out and finally reposed in a neat pile on the floor beneath the frame. Window braces are of little practical use.

"The shock from the blast wave acts very quickly and has been known to tear swinging doors from their hinges rather

than cause the doors to swing as might be expected. Blast vents consisting of light material which are easily blown out, will not in general function to protect the rest of the structure in the immediate vicinity of the bomb explosion, but it has been shown that less damage will be caused to window glass if windows are left wide open.

"Steel-framed structures designed in accordance with the principle of continuity, with particular attention to conditions of fixity at points where beams and columns are framed together, suffer little from the effects of earth shock. The result of impact (direct hit) and explosion must be distinguished from pure earth shock. The shock resulting from impact may, in addition to knocking down walls and even removing brick columns at some distance from the explosion, destroy some of the bonds between the steel and concrete of the intervening structure with resulting weakening and possible failure of beams and columns. It is quite clear, however, that steel-framed structures are much more resistant to collapse than any other type. Even a single important member of a frame is unlikely to be destroyed except by direct impact or when explosion is in contact with member. A near miss simply scars the steel with fragments and perhaps causes it to bend. The most serious effect results when a bomb bursts in the floor and displaces the base of a column; this may cause widespread damage.

"Experience definitely indicates that concrete members are more easily injured and are more difficult to repair than are steel members. I remember seeing an eight-storied block of flats of steel-framed construction, which had suffered a near miss by a heavy high explosive bomb. The bomb had landed quite close to one corner of the structure; the curtain walls at ground level had been blown in and out; the heavy steel corner-column had been sheared off as had the column next to it on the front and side of the building. Deprived thus of those main columns, the building showed only comparatively small signs of sagging and cracking. Brick or masonry wall-bearing structures, or any building

where walls support the roof and floors, suffer the greatest damage.

### Rescue Party and Demolition

"Apart from the leader and deputy leader, skilled men are not required for rescue party work; all that is needed are men physically suitable and susceptible to quick training. The recent tendency has been to make the rescue party, decontamination and stretcher party squads interchangeable. In some cases mobile skilled rescue parties are kept in reserve to attend incidents requiring special technical skill and those beyond the powers of the normal party. Such a mobile squad would include electricians, carpenters, plumbers, oxy-acetylene workers, etc. Comparatively little demolition work is done by the rescue squads. The bombs usually do the job fairly thoroughly except in the case of multi-storied buildings which are left to the big contractors who are organised and centrally directed for the purpose.

### Public Utility Services

"As might have been expected, in the case of underground services, steel pipes have proved very much more resistant than iron to fracturing. If there are failures, longitudinal splits are usual. A bomb bursting at 100 ft. will, however, be sufficient to cause serious fracture of cast iron pipes. Generally, some six or seven lengths of pipe have to be renewed, and jointing some distance each way required attention, but there has been one occasion at least where the jointings of almost a mile of pipes required attention.

"London has not experienced very much trouble with sewers. Rarely are sewer pipes under pressure—they conform to hydraulic grades. Accordingly, if a sewer is breached, temporary repairs to restore the flow can be made quickly.

"Underground electric power and telephone cables have stood up very well—much displacement can occur without causing a fracture. In the event of damage, to make a quick temporary restoration of service, it is usual to splice in a new section and lay the new cable over the ground, either placing ramps over it or removing wood blocks where

necessary to permit traffic passing over without damaging the cable.

"Blast has caused very little damage to overhead wires. Interruptions occur chiefly in those cases where a supporting standard has been brought down by a hit or near miss or where insulators are broken by flying splinters or fragments.

"England has been particularly fortunate in regard to her power stations but, as some of you will know, they and their machinery and equipment are heavily protected. Little can, I am afraid, be done to prevent possible movements of the bases of turbo-alternators following very near misses.

### Discussion

"In connection with disturbances to gas supplies, especially for cooking purposes, the disabilities had not been as great as might have been expected. Some people, of course, had been fortunate enough to have available an alternative utility service. Others had resorted to coal fires, oil cookers or open fires, while some had had recourse to communal kitchens.

"Trailer pumps had proved invaluable and were mass-produced and used in thousands throughout England. They were a valuable piece of equipment for fire brigades, and were recommended especially for use by large factories and by commercial undertakings, hospitals and the like. The most important thing to guard against was failure of the water supply, and auxiliary supplies should be available either through supplementary special mains or in the form of ponds, tanks, etc.

"Steps taken to deal with interruptions to the telephone services included the laying on the surface of emergency cables, in order that prompt restoration of the service might be effected."

**Priorities vs. Allocations.** ANON. J. Am. Chem. Soc.—News Ed. 19: 1480 (Dec. 25, '41). Priorities and allocations systems are methods to meet most urgent demands of world's largest armament program plus most prodigious consumer demand in all history. Obviously there are and will be shortages. Controls used mostly to date are priority ratings, a

means to make first things come first. A mfr. making something that nation vitally needs, gets high rating. One making something needed less imperatively, gets lower rating. System works well when shortages moderate. Inadequate when shortages are serious. Finally, fails to provide control that must be had. That point now reached, necessitating resort to allocations—rationing. Allocation system must be based on adequate detailed picture of future national requirements, military and civilian, bal-

anced against equally detailed picture of nation's supply of all critical materials. Steps to get these pictures already taken. Completion expected in few months. Programs can then be evolved to divide metals and materials among and according to essential industries. Also planned to set up reserve supplies to give temporary help to mfrs. facing absolute shut-down, enabling them to enter some other type production or work out usage of a plentiful substitute material.—*Ralph E. Noble.*

### INDUSTRIAL WATER SUPPLY

**A Process for the Treatment of Industrial Water Supplies.** H. W. BANNISTER, W. F. GERRARD AND LIVERPOOL BORAX CO., LTD. Br. Pat. 527,153. Industrial water supplies, such as those for high-pressure steam plants, laundries, artificial-silk factories, etc., may be treated by addn. of finely divided reactive magnesium oxide in sufficient quant. to combine with any free carbon dioxide and/or calcium, magnesium, and sodium bicarbonates present. Sodium carbonate formed will react with any calcium sulfate present. Magnesia also reduces content of silica in water. By adding barium hydroxide to water treated with magnesia, barium sulfate and carbonate pptd. and magnesium hydroxide formed. Excess barium hydroxide may be pptd. with carbon dioxide gas. Total content of dissolved solids reduced by this treatment.—*W. P. R.*

**Baltimore Will Sell Sewage Effluent for Industrial Water Supply Use.** ANON. Eng. News-Rec. 127:73 (July 17, '41). By recent agreement, Bethlehem Steel Co., Sparrows Point, Md., will purchase up to 40 mgd. of treated sewage from Baltimore for use in steel processing at cost of about \$24,000 annually. Static levels in company's wells fallen as much as 100' and salt water intrusion occurred. Activated sludge system used for treatment of about  $\frac{1}{2}$  of Baltimore sewage and trickling filters for remainder. Tests indicated that activated sludge effluent satisfactory for use if treated further by chem. pptn. Company will

spend about \$2,000,000 on constr. of 48" pipe-line (4 mi.) and treatment plant. Specifications require that sewage supplied meet following std.: (1) pH 6.5-7.8; (2) monthly avg. suspended solids not over 25 ppm., with instantaneous max. of 50 ppm.; (3) monthly avg. 5-day B.O.D. not over 25 ppm., with instantaneous max. of 45 ppm.; (4) chlorides not over 170 ppm. Payment arranged on sliding scale as follows: less than avg. of 25 mgd., \$1,000 per mo.; 25-37.5 mgd., \$1,500 per mo.; over 37.5 mgd., \$2,000 per mo.—*R. E. Thompson.*

**Monongahela River—Steel Plant Water Supply.** J. C. JAMISON AND J. M. HARVEY. Blast Furnace & Steel Plant. 29:989 (Sept. '41). To vast and complex power and steel industries, character of Monongahela R. water of paramount importance. Of glacial origin, it is river above river. Underground flow exceeds that above during droughts, has even temp., 54-57°F., and passes through glacial deposits of sand and gravel. Formerly of a bicarbonate character, surface water has become acid from poln. by mine and steel pickling waste. Remedies consist of mine sealing, flood control dams and sewage disposal. Avg.  $H_2SO_4$  content of mine water estd. at 200 gpg. Sealing of abandoned mines excludes  $O_2$  from pyritic material, preventing  $H_2SO_4$  formation. Effluents from sealed mines alk. Illegal to seal off any part of active mine. Flood control dams impound alk. water upstream from industrial areas. When released,

such water greatly reduces downstream acidity and hardness by dilution. Considerable text devoted to treatment of condenser and boiler waters. Editor of publication asks: (1) why is not more use made for cooling purposes, of vast underground supply with even temp. as threshold treatment permits economical elimination of scale formation; and (2) as supply of flood control water to rivers increases and raises pH to 6.5-7.5, where primary breakdown of sewage is active, will sewage disposal become necessary to cope with resulting conditions?—*Ralph E. Noble.*

**Current Methods of Purifying Water for the Pulp and Paper Mill.** A. F. McCONNELL. Paper Trade J. **112**: 26: 89 ('41). Discussion of constituents in water which make it undesirable for use as process water in pulp and paper industry, together with description of several means, including zeolites, Spaulding precipitators and sand filters, for effecting their removal or reduction.—C.A.

**Water Treatment at Escanaba Paper Mill.** I. W. JOHNSTON. Paper Trade J. **112**: 18: 31 ('41). Escanaba R. flow fluctuates greatly, causing wide change in org. matter content. Water problem consisted of org. coloring removal and pH correction. Raw water contains 30-200 ppm. org. coloring matter and has pH ranging from 7.0 to 8.0, and requirements vary from 200 to 2,100 gpm. Through installation of modern purif. plant and efficient control, mill being supplied with water contg. 5-20 ppm. coloring matter and having pH of 6.8 to 7.1.—C.A.

**Water Treatment at the National Container Paper Mill.** R. C. RICHTER AND F. J. LAMMERS. Paper Trade J. **112**: 19: 31 ('41). Critical  $H_2S$  corrosion of Fourdrinier wires and other water-handling equipment for producing sulfate pulp and liner overcome by chlorination of water. Excessive water sealing of screens, deckers, piping and throughout mill traced to  $CaH_2(CO_3)_2$  to exclusion of other hardness. Softening equip., installed for selective removal of

$CaCO_3$ , eliminated sealing, shutdown and cleaning losses. Essentially pure  $CaCO_3$  sludge reburned with causticizing lime, recovering both lime used in softening and addnl. lime from water.—C.A.

**Water.** J. RAUX. Brasseur Franç. (Fr.) **4**: 7: 140 ('40). Author discusses various components which may be present in brewing water. Iron in concn. greater than 1 ppm. has deleterious effect on diastatic enzymes in mash tube since it can combine with proteinous matters and cause clarification difficulties in worts and beers. Can be eliminated as iron hydroxide by aeration and filtration. Carbonates and bicarbonates have unfavorable influence by neutralizing wort acidity, thus curtailing enzyme action, as well as extracting undesirable bittering substances from malt and hops. Chlorides and sulfates of calcium and magnesium, on other hand, and sodium chloride in small quant., desirable, favoring clarification and mellowness in taste, and supplying yeast nutrients. Silica in excess of 50 ppm. can cause trouble. Appears to be involved in certain turbidities.—C.A.

**Water in the Brewery.** MORRIS A. POZEN. Modern Brewery Age. **23**: 3: 67 ('40). Silica, usually present in small amts. in most waters, sometimes found in certain beer sediments. Iron, normally present in small amts., can affect color and taste. Aluminum, in small amts. commonly present in water, relatively unimportant. Calcium and compds. important. Calcium bicarbonate and carbonate, chiefly because of alk. effect, undesirable. Calcium sulfate in reasonable amts., on other hand, beneficial constituent of mash water for pale beer. Magnesium and salts act somewhat like those of calcium. Moderate amts. of sodium chloride beneficial in mash water. Sodium carbonate and bicarbonate very undesirable because of alky. *Ibid.* **23**: 4: 76; 5: 70. Review. *Ibid.* **24**: 1: 62 ('40). Biological purity essential in steep water. In steeping, water gradually dissolves out of barley sugars and soluble protein derivatives, becoming excellent growth medium for

bacteria. If bacteria already present in marked quant., germinating barley can become polluted. Steep water should be practically free from bacteria, molds and mold spores, as well as decaying or decayed vegetable or animal matter. Should also be free from any objectionable odor or taste. Best barley steep water of medium hardness. If too soft (low in dissolved solids), excessive proportions of mineral salts and soluble protein derivatives, which are valuable yeast nutrients, may be dissolved out of barley. On other hand, hard water (very high in dissolved salts) will not extract certain undesirable constituents. Unless broken kernels present, mineral ions of steep water do not enter barley kernel, as cell wall acts like semi-permeable membrane. Principal husk constituents, considered undesirable and removed in steep, mostly tannins, resins and bitter substances. All of these acid in character and therefore more readily soluble in weakly alk. waters. For this reason, steep waters either naturally alk. or rendered so by addn. of lime. Alk. steep waters also less likely to permit growth of micro-organisms. Brewing water used to produce beer should meet bacteriological requirements for drinking water. Bicarbonate and carbonate hardness undesirable, tending to inhibit enzyme activity, increase color and impede clarification and conversion. Permanent hardness of calcium sulfate type valuable in promoting better clarification and conversion, in producing paler wort and mellower flavor and in providing yeast nutrients.—C.A.

**Water Supplies in Relation to Surface-Taint Butter.** J. B. LINNEBOE. Sci. Agr. **21**: 133 ('40). *Achromobacter putrescens* in water supplies of creameries often cause of surface taint in butter. 6 out of 55 farm sources of water contained organism.—C.A.

**The Water Supply and Off-Flavors in Butter.** V. L. TURGAEN. Natl. Butter Cheese J. **31**: 16: 39 ('40). Organisms occurring in water used in creameries may be responsible for off-flavors in butter. Salting butter (2.5%) did not

prevent this, but treatment of water with chlorine found to destroy micro-organisms. Conens. of chlorine required in some cases large enough to necessitate de-chlorination of water with activated carbon. Pasteurization of water considered too costly.—W.P.R.

**Sodium Pentachlorophenate Treatment for Cooling Water.** M. GELFAND. Power Plant Eng. **45**: 60 (May '41). Use of sodium pentachlorophenate suggested to replace chlorine for algae control in spray ponds. Lab. tests indicate following advantages: less cost, not effected by heat, not pptd. by CO<sub>2</sub>, less corrosive, less toxic in handling.—T. E. Larson.

**New Westinghouse Plant Features Modern Engineering.** ANON. Am. Chem. Soc.—News Ed. **19**: 842 (Aug. 10, '41). Among many other features, air-cooling for process control accomplished by circulating 3,600 gpm. of water at 55°F. from nearby abandoned and sealed coal mine through heat-exchanging reservoir just outside bldg., where it is used to cool closed circulation system of ordinary city water flowing through copper cooling coils in bldg. Mine water then returned to mine through drill hole.—Selma Gottlieb.

**New Methods of Purifying Water for the Ceramic Industry.** W. S. MORRISON. Bul. Am. Ceram. Soc. **20**: 246 ('41). Inorg. and org. zeolites discussed, also theory of exchange absorption. Use of hydrogen and hydroxyl exchangers emphasized and prepn. of these resinous materials described. Use of exchangers has removed one variable from enameling problems.—C.A.

**Skillful Operation to Move Water Tank.** G. B. BEAUMONT. Eng. Cont. Rec. **54**: 16: 14 (Apr. 16, '41). Development of heavier motive power resulted in extension of distance between water stations on railroad lines from 10 up to 40 mi.; in northern Ont., 35-mi. intervals most practical. Tanks now largely of steel, and capac. ranges from 40,000 to 85,000 gal. When renewal of tank be-

comes imperative, replacement usually involves relocation of other water tanks to fit into ultimate plan of water service. In most cases, tanks must be completely dismantled, but when possible moved intact, operation being accomplished in fraction of time and at fraction of cost. Recently, Canadian Natl. Ry. moved 41,600-gal. steel tank and set it up in new location 13 mi. away in single day. Tank, 21' in diam. and weighing 50 tons, supported between booms of 2

Brown hoist cranes during moving, base plates at ends of 25' legs being about 4' above ties. Including ball indicator mast towering 20' above roof, overall height above rails was 69'. Line traversed had 34-rock cuts and many sharp curves. In majority of cuts, necessary for men to walk beside and guide legs: in one case, clearance only 1½" on either side. Curves ranged up to 6°, with super-el. of outer rail up to 6".—*R. E. Thompson.*

### U.S. WATER SUPPLIES—GENERAL

**Results of a Survey of Water Supply Control Practices.** ANON. Am. Pub. Health Assn. Yearbook Suppl. **31: 75** (Mar. '41). Report based on results of questionnaire sent to 1,490 w.w. supts. of whom 410, or 28% replied. 10% of replies indicated sampling schedules inadequate to assure san. qual. of water delivered into mains. Sampling schedules especially inadequate where sterilization is only treatment. Water delivered to mains should be free of coliform organisms to improve detection of localized poln. More water works should have local labs., especially where only treatment sterilization. Water in open reservoirs subject to poln. and means for chlorination generally lacking. Sampling at points on distr. systems inadequate and should be extended as means of detecting local poln. Break-point chlorination promising as means of maintg. qual. of water in distr. systems and as aid in checking bad effects of local poln. About ⅓ of those who replied report cases of local poln. caused by back-siphonage, cross-connections, and repairs to system. Another ⅓ report zero pressures over large sections of distr. systems due to inadequacy of system, excessive consumption, floods, droughts, pipe failures, power failures and large fires. Recording pressure gages on various parts of distr. systems advisable for detecting low pressure areas which are danger areas for local poln. Cross-connections prohibited in ⅔ of cities reporting, and permitted in remaining ones under restrictions. Replies indicate increasing effort to

train personnel how to handle emergencies affecting qual. of water supply. Need for extending control over distr. systems including house connections and plumbing.—*P.H.E.A.*

**Technological and Economic Results of the Operation of Large Plants for the Purification of Water in the United States of North America.** FRANCO CAMPI. Atti Ing. Lombardia. (It.) **19: 1** (Jan. '41). Since necessity has arisen for expanding water works to include utilization of river and lake waters for drinking as well as industrial purposes, Italy looks toward U.S. as best example of good practice from eng., economic and health aspects. Water supply problem solved most effectively in U.S. and more statistical data available than in any other country. Author points out that, as U.S. developed, water most easily (i.e., economically) available was used. Increase in pop. with resultant increase in water consumption, soon caused health problem with many typhoid deaths occurring. Bacteriological advances in latter half of 19th Century made possible isolation of cause of epidemics, and engrs. called upon to solve problem. At first, slow filtration plant set up in Poughkeepsie, N.Y., after most prevalent method in Europe at time. Later, this abandoned in favor of quicker method of rapid sand filtration and subsequent disinfection by chlorination. Immediate effect of treatment was marked decrease in typhoid death rate. Illustrated by a table show-

ing: (1) pop. of cities from various sections of U.S.; (2) source of water supply; (3) treatment accomplished; (4) typhoid death rates from 1880 to 1938. Emphasis laid on progress U.S. has made in utilization and purif. of water from various sources which would otherwise prove menace to pop. Article points out increase in publicly owned and operated water works and brings out fact that Italy should, as America and France do, regard safeguarding of citizens from epidemics due to water-borne diseases as civic obligation. Although they find that water works operation requires enormous sums of money, they also find that all, except plants in small cities, are self-supporting, as earnings from public services (water and electricity supplies) largely cover expenses.—*V. Medici.*

**Trouble Shooters at Work.** J. S. LONGWELL. *Eng. News-Rec.* 126: 956 (June 19, '41). Organization and procedure employed by East Bay Munic. Utility Dist. for emergency service described. Dist. comprises 9 cities and area of about 200 sq.mi., pop. being 540,000. Supply system consists of 93-mi. aqueduct from Pardee Reservoir on Mokelumne R., 5 filter plants and 4 terminal reservoirs. Distr. system includes 1,800 mi. of mains, 44 pumping plants, 23 reservoirs and 45 tanks. Aqueduct, which is 61-65" in diam., patrolled daily and extra pipe sections, portable welding machine, pumps for unwatering trenches, and excavating equip. available for emergencies. Aqueduct includes 4 automatic wasteways to prevent damage by escape of water in event of break and pressure increases which aqueduct not designed to withstand. Flow increase resulting from break causes greater differential in pressure between full section of pipe and Venturi section, which actuates butterfly valve shutting off flow and needle valve releasing water into wasteway. Filtered water storage amts. to 317 mil.gal., 7 days supply on basis of avg. consumption of 45 mgd., and 5 days at summer peak of 60 mgd. Most of pumping stations automatic. Portable gas-engine-driven pump used for pump-

from 1 zone to another in case of power failure and portable gas-engine-driven elec. generator being assembled for emergency use. Special truck maintd. for servicing many pressure regulators required, unit being employed also for inspecting and servicing double check valve installations. Maint. trucks used at night painted white as safety measure. Complete records of locations of pipe, gate valves, etc., available and shown on maps supplied to all foremen.—*R. E. Thompson.*

**Philadelphia Decides on Water Supply Program.** NATHAN B. JACOBS. *Civ. Eng.* 11: 606 (Oct. '41). One very serious phase of Philadelphia water problem has been lack of a clear-cut, definite program of development and, since adoption of supply system completed in '13, lack of consistent policy of upkeep, maint. and improvement. Emphatic approval of bond issue by voters in '40 evidence of favorable public reaction to decision of Mayor and City Council to reject idea of upland source in favor of proceeding promptly with improvement of existing facilities. Original units of system, as developed under 1899 program, continued in use, but certain adjustments made from time to time, such as installation of rapid sand filters to replace certain of original roughing filters and substitution of elec. power for steam in some of pumping stations. As shown in figure, city now divided into 10 dists. for distr. of water supply. Rehabilitation of purif. works, as planned, includes: (1) constr. of modern type coagulating and sedimentation basins and improved chem. and mixing facilities; (2) constr. of modern rapid sand filter plants; (3) adoption of policy of double filtration for entire supply, utilizing existing slow sand filters as final or polishing units for effluent from rapid sand filters; (4) installation of suitable equip. and treatment facilities for overcoming taste and odor difficulties; (5) installation of more modern and improved chlorination equip.; and (6) adjustment of intake structures and raw-water pumping stations to provide additional capac., economical operation, and uninterrupted

service. Changes proposed will result in important improvements in services and economies in constr. and operation, some of which are: (1) low-pressure pumping equip. will not be required to meet max. hourly demands; (2) material savings in power costs will result; (3) improved facilities will become available for extending service either from Torresdale or Queen Lane plants at times of high demand. Troublesome phase of Philadelphia's water problem to determine source of supply, but this should cease now that definite decision made, money voted, and plans in process of development for the letting of constr. contracts.—*H. E. Babbitt.*



#### A City Buys a Distribution System.

CARL F. LAMBERT. Eng. News-Rec. 127: 557 (Oct. 23, '41). Water supply of Miami, Fla., derived from wells, filtered and softened in 40-mgd. purif. plant. Supply and purif. system owned and operated by city since '25, treated water being pumped 10 mi. by city-owned and operated facilities to surface storage tanks of 15-mil. gal. capac., from which 4 pressure pumping stations, 3 privately owned, take their suction. Fourth pumping station, owned and operated by city, pumped 90% of consumption into

distr. system owned by water co., city being paid for service at rate of \$7.50 per mil.gal. pumped. City-owned station equipped with steam turbine-driven pumps, operated by steam from adjacent munic. incinerator. In addn. to pumping stations mentioned and distr. system, co. owned 1-mil.gal. elevated tank and 2 booster stations. High-pressure fire system in downtown area, consisting of well supply, pumping stations and distr. facilities owned and operated by city, that also owned all fire hydrants on water co.'s distr. system, and was charged rental for same. Co. made collections from individual consumers in Miami area. To regular bills, 50% surcharge was added and this, less 5% collection charge, went to city in payment for production and purif. costs. Co. also made collections on wholesale basis from Miami Beach and Coral Gables, surcharge of 75% being made and paid to city. For no. of yr., Miami tried to acquire distr. system, but co. indicated no desire to sell and city lacked legal sanction to condemn property. No. of controversies developed, which involved also street ry. system operated by another subsidiary of co., and in '38, co. expressed willingness to sell, provided all controversies could be settled. Board of 3 engr. appointed and agreed on reproduction value, as of Aug. 1, '38, of \$4,734,413, exclusive of depn., paving, and going value. Eventually, sale price of \$4,500,000 agreed upon and ratified by electors. Separate dept. of water and sewers set up by city and all employees of water co., except executives, taken over. By legislative enactment, proposed to place dept. under water board, independent of city commission. Anticipated that new dept. will be able to pay about \$200,000 annually into general fund of city, in addn. to paying taxes. City will pay rental of \$30 per yr. per hydrant and dept. will pay city \$50,000 per yr. in lieu of taxes.—*R. E. Thompson.*

**The New Water Works of Springfield, Mo.** L. R. Howson. W. W. & Sew. 88: 241 (June '41). Water supply for Springfield, Mo. obtained from 24" drilled well and reservoir on Sac R.

6-mgd. filtration plant and pumping station replaced by modern 12-mgd. plant. Because of unavailability of elec. power, plant includes two 252-hp. steam boilers and turbine-driven pumps. Elec. power for raw water pumps 3 mi. from plant obtained from turbine-driven generator. Filtration plant consists of mixing basin, 40-min. detention flocculation chambers and 3-hr. detention sedimentation basins. Although raw water turbidity reaches 1,000-ppm. baffled settling basin design has reduced turbidity of water going to filters to less than 3 ppm. Filter piping designed for 36" rise. Expts. on surface washing have reduced mud balls 35% in 2 wk. Chlorine applied at raw water pump, mixing chamber and when necessary on leaving plant. Ammonia applied at clear well. Cost of plant approx. \$850,000.—*F. J. Maier.*

**Baltimore Water Demands Exceed Safe Supply Limits.** ANON. Eng. News-Rec. 127: 625 (Oct. 30, '41). Unusual demands for water because of defense industrial activity, coupled with deficient rainfall in Aug. and Sept., made it necessary to draw on reserve water storage supplies. Since Sept. 5, 4 billion gal. drawn from 19.7-billion gal. lake created by Pretty Boy Dam, reserve storage project built in '33 and never before drawn upon. Demand in Aug. and Sept. averaged 153 mgd., highest on record and 5 mgd. more than estd. safe yield of supply. During first 8 mo. of '41, 6,150 new services added to system compared with 5,600 during preceding 24 mo. Plans for supplementary supply of about 85 mgd. under study for some time. Five possible sources considered include Susquehanna R. and some tributaries, Patapsco R. watershed and enlargement of storage facilities of present Gunpowder R. supply.—*R. E. Thompson.*

**Seventy-Fourth Annual Report, Bureau of Water, Erie, Pa., for Year Ending Dec. 31 '40.** Extensive tabulations of operating and financial statistics presented. Avg. consumption 25.27 mgd., equivalent to 208.85 gal. per capita to estimated pop. supplied of 121,000.

Cost of collecting, purifying and pumping water, including depn., \$32.311 per mil. gal. No. of gal. of water pumped per lb. of coal used avgd. 377.05. Surplus on yr.'s operation \$44,202.07. Water furnished for city purposes free of charge amtd. to \$65,179.91. Length of mains in use 290 mi., only 5 mi. being less than 4" in diam. No. of hydrants 1,564 and no. of services (galvanized wrought iron, c-i. and copper) 32,911, 5,900 of which not in use. Avg. length of services 16'9" and avg. cost of services laid in '40, \$24.94. 1,224 meters in use, 4.5% of services being metered. Metered services provide 30.41% of revenue. Schedule of rates included, together with summary of assessments for unmetered water for various uses. Avg. amts. of chems. used at Chestnut St. and West filter plants, respectively: alum, 0.29 and 0.217 gpg.; chlorine, 1.59 and 1.62 lb. per mil. gal.; activated carbon, 2.62 and 2.73 lb. per mil. gal. Wash water used was 1.77 and 1.09% of water filtered at 2 plants, respectively. Tabulation of anal. data shows monthly avg. bacteria per ml., *Esch. coli*, turbidity, alky. and color of raw and filtered water and avg. temp. All 914 samples of filtered water examd. for *Esch. coli* in 10 and 1 ml., were negative. Turbidity of filtered water avgd. zero, color 10—, and monthly avg. alky. varied between 83.6 and 89.5 ppm. Supply drawn from L. Erie. Capac. of Chestnut St. and West plants 32 and 16 mgd., respectively.—*R. E. Thompson.*

**Denver Plans Addition to West Slope Water Supply.** ANON. Eng. News-Rec. 127: 275 (Aug. 28, '41). Plans for diversion of West Slopes water from Blue R. through 23-mi. Continental Divide tunnel into present South Platte R. system have been revived by appropriation of \$50,000 for further studies and surveys. Preliminary plans are for 8 x 10' tunnel with capac. of 800 cfs. which could be enlarged to 14 x 16' to carry twice this flow. Project surveyed in '24 but delayed by use of pioneer bore of Moffat tunnel for diversion of West Slope water. Later, Williams Fork diversion through 3-mi. Jones Pass tunnel completed. Contract let recently for extension of

collecting works for Moffat tunnel diversion by driving 3-mi. Arrow tunnel north from intake to tap headwaters of Ranch Creek.—*R. E. Thompson.*

**Laying a Deep Intake in Lake Michigan.** ANON. Eng. News-Rec. **126**: 740 (May 8, '41). Constr. of 30" steel intake, 4,620' long, part of Muskegon Heights, Mich., \$1,200,000 water works improvement project, described. Line, (capac. 15 mgd.) laid largely in 120' lengths. Std. sections 60' long and  $\frac{3}{8}$ " thick, longitudinal seam and girth joints being butt-welded by shielded arc process. After being tested hydrostatically to 200 psi., sections cleaned, grit-blasted and machine-enameled inside and out with special coal-tar pitch. Two std. lengths welded together in shop and, to facilitate handling, lifting lugs provided at 30' intervals. 45-ton full revolving steel frame crane with 85' boom used for excavation, backfilling and laying of pipe. Depth of trench varied from 9 to 20'. Joints made with mech. couplings. Avg. time required for lowering section into place, sandbagging, coupling and inspection about 5 hr.—*R. E. Thompson.*

**Million-Dollar Improvements to Everett Water Supply.** ANON. Am. City. **56**: 8:41 (Aug. '41). Because of pulp mills, canneries and an Army air base at Everett, Wash. seasonal peaks in water consumption occur during low summer stream flows, necessitating more storage capac. Storage in L. Chaplain, fed by springs and through a diversion tunnel from Sultan R. being increased over threefold to 4,500 mil.gal. by raising dam and bldg. dikes. Other improvements include wood-stave pipe from river to lake, repair of tunnel linings, constr. of reservoir headquarters bldg., 20-mil.gal. distr. reservoir and various road relocations. Over 75% of cost obtained from W.P.A. funds.—*F. J. Maier.*

**Remodeling a Water Supply, New Wells and Dual Power.** F. K. BALCH. Am. City. **56**: 12: 69 (Dec. '41). Fire insurance underwriters required that one of three well pumping units on Turlock, Calif., water system should have double source of power. Vertical shaft on well

pump now driven by electric motor and through 30' shaft from gas engine. 18" diam. central well was air-driven to required depth. 8" diam. wells then driven on either side and 6' from central well. With central well pumped and removing sand, 50 to 60 cu.yd. gravel fed into small wells. Beside realizing reductions in fire insurance rates, only one man required part time to operate present system instead of five, full time.—*F. J. Maier.*

**Multiple-Floor Plant of Yankton Water Works.** ANON. Am. City. **56**: 12: 73 (Dec. '41). Lowest floor houses three 1,200-gpm. low-lift pumps taking water through two intakes in Missouri R. Discharged into primary settling basin, water flows by gravity to mixing chambers, coagulating basins and filters. Three 2-mgd. filters on third story of plant drain to high-lift pumps on level below. Yankton's (S.D.) 10,000 pop. served avg. of 500,000 gpd. Raw Missouri R. water has hardness of 137 ppm. Plant delivers water of 74 ppm. hardness.—*F. J. Maier.*

**A Two-Supply City.** R. G. DAVIES. W. W. Eng. **94**: 564 (May 21, '41). Grand Forks, N.D., (pop. 20,000) obtains water supply from either or both of 2 sources—Red R. with drainage area of 40,000 sq.mi. and Red Lake R. with 5,760 sq.mi. Source changed from one to other because of condition of water of either supply influencing cost of treatment and phys. conditions. Water softened with lime and soda ash using Spaulding process; chlorine, carbon, alum or sodium aluminate, sodium hexameta-phosphate and ammonia are the other chems. employed. Avg. cost of treatment of Red R. water in '40, \$30 per mil.gal. Plant has 8 filters with capac. of 3 mgd.; avg. consumption is 1.5 mgd. Modernization of treatment plant and installation of new Red R. intake done in '39. History of supply given.—*Martin E. Flentje.*

**From Mule-Cart Water Delivery to a Monumental Storage Tank.** ANON. Eng. News-Rec. **126**: 553 (Apr. 10, '41). Water system recently completed, with

aid of P.W.A., in Roma, Tex., consisting of intake in Rio Grande R., aerator, mixing basin, rapid sand filter, clear well and pump house. Pump designed to deliver 250 gpm. to 60,000-gal. steel storage tank supported on reinforced concrete tower, 100' high. Hollow cylindrical tower 11' in diam. and walls 10" thick. External reinforcing ribs of

concrete, which extend whole height of pedestal and terminate in parabolic curves at base and upper platform slab, not only provide addnl. strength but add to appearance of structure. Prior to completion of water system, town depended upon mule cart deliveries of Rio Grande water. Cost of project \$110,000.—*R. E. Thompson.*

### CANADIAN WATER SUPPLIES—GENERAL

**A Review of Canadian Water Works Practice.** ANON. Can. Engr.—Wtr. & Sew. 79: 6: 82 (June '41). Nearly all water works municipally owned. Systems tax-exempt and operated at cost. At end of '40, 1,275 public supplies, serving 54% of Dominion's 11,334,000 pop. In Ont. 60% of pop. so served. Canada's supply of fresh water estd. to be largest of any country in world. Computed that more than half total fresh water on surface of earth contained in Great Lakes system. Lack of low-cost coal and abundant supply of elec. energy has made elec.-operated pumps first choice. 47 pressure filter plants, 12 slow sand and 68 mechanical plants. Latter include about 335 individual filters. Pop. supplied by modern gravity plants totals about 3½ million, while pressure filters serve only 225,000. Spiral flow mixing tanks used extensively and settling periods vary from 2 to 4 hr. Chlorination widely employed in all provinces except B.C. In Ont. 80% of water supplied is chlorinated. In '39, avg. consumption 109 gal. per capita. Depth of mains varies from 4 to 9'. Length of mains avgs. 8.1' per person served. No. of services per mi. of mains is 111 and 4.2 persons is avg. no. on each service. Avg. cost of water for 5-room house assessed at \$2,000 is \$16.00 per yr. flat rate basis. Avg. for metered supplies \$14.45. Water costs during '39 avgd. \$4.83 per capita, including debt charges of \$2.14. Avg. cost per 1,000 gal. for 34 of larger supplies 13.75¢.—*R. E. Thompson.*

**Highlights Reflecting Canadian Water Works Practice.** M. N. BAKER. Eng. News-Rec. 126: 889 (June 5, '41). By

1900, of 12 cities in Canada for which filters had been constructed, only one, Victoria, B.C., had adopted slow sand filtration. First mechanical filters built in Canada were at Winnipeg, in 1887. Winnipeg also first city in North America to employ softening, plant being placed in commission in '01. Hamilton, Ont., first city on record in Western Hemisphere to use infiltration basins. Large open basin constructed in 1859 and not abandoned until '28, although supply had been supplemented by enlargement and by taking water directly from L. Ontario during intervening yr. Toronto infiltration basin, built in 1875-8, short-lived. Subsequently Toronto completed slow sand plant in '11, drifting sand plant in '16 and standard rapid sand plant a few months ago. Chlorination commenced in '10. Drifting sand plants constructed later at Brampton, Oshawa and Rockland, Ont., and Jamaica, B.W.I. These all abandoned, but as far as is known, in addition to Toronto plant, initial one at Merthyr Tydfil, Wales, and one at Pernambuco (Recife), Brazil, still in operation.—*R. E. Thompson.*

**Efforts for a Pure Water Supply in City of Toronto.** ANON. Eng. Cont. Rec. 54: 32: 20 (Aug. 6, '41). Account of trials and tribulations attending development of Toronto's water supply. First power-driven pump installed 100 yr. ago by City of Toronto Gas, Light and Water Co. to supply pop. of 15,000. Contract was for supplying water principally for fire protection, but domestic supply also furnished through street taps at which jugs and buckets could be filled. Supply derived from Toronto Bay and distrib-

uted through wooden conduits. Water system purchased from company in 1873 for \$220,000, pop. then being 68,000. After thorough investigation of all possible sources, L. Ontario chosen because of accessibility and comparative purity of water. Infiltration basins with designed capac. of 20 mgd. excavated on island which encloses Toronto Bay, but only 4 mgd. obtained. Channels then dug connecting basins with lake. Wood-stave intake pipe, 72" in diam., laid in 1881, extending  $\frac{1}{2}$  mi. into 25' of water. Considerable difficulty experienced due to floating of pipes conveying water under bay and, finally, in '05, concrete and brick tunnel of horse-shoe section equivalent to 90" diam. constructed. Tunnel still in use for conveying water from 2 island filtration plants to mainland. Now are 2 steel intake pipes supplying island plants and new intake and purif. plant just completed in east end of city.—*R. E. Thompson.*

**Improved Water and Sewage Systems in St. Lawrence River Towns Will Result From Waterways Development.** ANON. *Can. Engr.—Wtr. & Sew.* 79: 9: 15 (Sept. '41). Water supply and sewage disposal in Cornwall, Morrisburg, Iroquois, Prescott, Cardinal and Brockville discussed in relation to proposed St. Lawrence Waterway development. All these communities derive water supplies from river, chlorination being sole method of treatment. Sewage discharged untreated except at Cardinal, which employs sedimentation. For many yr., river used for dual purpose of water supply and convenient outlet for sewage and wastes of all kinds, reliance being placed on great dilution available. Desirable that plans should be formulated now for dealing with water treatment and sewage disposal in satisfactory manner.—*R. E. Thompson.*

**Water Supply Problems in City of Longueuil, Que.** RENE CYR. *Eng. Cont. Rec.* 54: 26: 44 (June 25, '41). Water supply drawn from St. Lawrence R., auxiliary pump being employed for about 2 mo. each yr. when river el. below limit for gravity operation of intake.

Purif. effected by 2 vertical and 3 horizontal pressure filters operated at rate of 2 gpm. per sq.ft. Vertical units installed in 1887. Alum and chlorine applied prior to filtration. Elevated tank of 60,000-gal. capac. provides static pressure of only 47 psi. and practice has been to close valve to tank whenever fire occurs. For past 2 mo., valve has been kept closed and pressure at pumping station increased to 80 lb. as temporary remedy for complaints of low pressure. Consumption increased from 0.9 to 1.1 mgd. during period Jan.-Apr. of '41. In addn. to 8,000 pop. of Longueuil, 2,000 people in Montreal South served by system. New 27" concrete intake and suction well partially completed.—*R. E. Thompson.*

**Improvements to Scarborough Water Works System.** RONALD HARRISON. *Can. Engr.—Wtr. & Sew.* 79: 12: 11 (Dec. '41). Scarborough Twp. is plateau with steep bluffs, 100-250' high, forming shore line along L. Ontario. Low-lift pumping station located on beach at foot of gulley and connected by 12" c-i. main to filter plant and high-level pumping station, 180' above lake level, at top of gulley. Water derived from lake through 5-mgd., 24" steel intake pipe extending 2,560' from shore into 25' of water. Electrically-operated low-lift pumps can be operated by remote control from high-lift station and gasoline engines provided for standby use. Alum used as coagulant and water filtered through four 0.5-mgd. filters. In '40, East York Twp. used  $\frac{2}{3}$  of 1.5 mgd. avg. pumpage. At present time, avg. pumpage nearly 2 mgd., rate at times being as high as 4 mgd. Storage from which this excess pumpage can be drawn consists of 1.5-mil.gal. clear-water reservoir and 90,000-gal. elevated steel tank. Recently completed improvements include second pressure main from low-level station to filter plant, mixing chamber and flocculation basin, dry-feed equipment, 2,000-gpm. electrically-driven pump in low-lift station, 20" Venturi meter and recorder, chlorinator and wash water pump. New pump equipped with automatic submerged-suction priming equip. to protect it from damage resulting from possible

stoppage of intake by frazil ice, accumulation of air, etc. Pipeline, 20" in diam. and of 5 mgd. capac., and 8" drain pipe, installed in tunnel and vertical shaft, latter accommodating an elevator. Mixing chamber, replacing baffled basin, equipped with "Turbo" flash-mixer and "Dorreo" flocculators. Alum dosage now approx. 80 lb. per mil.gal., compared with former avg. of 100 lb. and max. of 150 lb. Coagulation basin provides retention of 2 hr. Filters contain 30" uniformly graded quartz sand and 18" graded gravel. Chlorine dosage 3 lb. per mil.gal. In case of ice troubles, intake can be back-flushed from high-level system. Doubling of filter capac. under consideration, as is additional coagulation and high-level pumping capac.—*R. E. Thompson.*

**Progressive Development of Orillia's (Ont.) Water System.** L. G. McNEICE. Eng. Cont. Rec. 54: 26: 38 (June 25, '41). Water supply acquired from private owners in 1883. Early sources of supply wells and springs, but in '02 intake laid in Lake Couchiching, now sole source of supply with exception of 2 gravel-wall wells installed in '39 for standby use and to supply cool water during summer. Pumping equip. consists of 3 centrifugal units, 2 driven by induction motors and other by gasoline engine. Purif. plant, installed in '14, comprises coagulation basin and 5 pressure filters with total capac. of 2.16 mgd. Storage includes 2 reservoirs of total capac. of 254,000 gal. at filter plant, 675,000-gal. reservoir at el. of 172' above lake level and 25,300-gal. elevated tank. Wells are near pumping station and are equipped with motor-driven turbines. During fires, pressure increased from normal of 50 to 130 psi. Avg. consumption during '40 was 0.916 mgd. or 99 gal. per capita. 27 mi. of mains, laid with min. cover of 5', and 156 public hydrants. Latter overhauled twice each yr. and examd. weekly during winter.—*R. E. Thompson.*

**Extension of Intake for Port Credit (Ont.) Water Works.** ANON. Eng. Cont. Rec. 54: 23: 11 (June 4, '41). Increased residential constr. and activity

at local military camps increased avg. consumption from 125,000 to 235,000 gpd. with peak rate of over 500,000 gpd. Original plant, built in '23 and consisting of intake in L. Ontario, pumps, sedimentation basin, 3 slow sand filters and elevated steel storage tank, has designed capac. of 300,000 gpd. Intake being extended 500' farther into lake to improve qual. of water obtained.—*R. E. Thompson.*

**Pump House Floor Lowered.** C. EDGAR BROWN. Can. Engr.—Wtr. & Sew. 79: 9: 21 (Sept. '41). Town of Meaford, Ont., for many yr. obtained supply from shallow basin built in 1895 near shore of Georgian Bay. Recession of water in recent yr. lowered level of water in supply basin and troubles have been experienced due to algal tastes. After considering various possibilities, decided to construct well on same site. Well is of gravel-wall type, with angle-type screen, and is 23' deep. Silt and sand removed during development replaced by screened and graded stone. Feature of work lowering of level of pump house floor and 2 elec.-driven pumps about 9' to create better suction conditions, accomplished without interrupting supply. Water palatable and of good qual., but somewhat harder than old supply, which is still required during summer. Expected that at least one more well of similar type will be constructed and old supply abandoned.—*R. E. Thompson.*

**Annual Report, Brantford, 1940.** ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 5: 5 (May '41). Water drawn from Grand R. through infiltration basin and subjected to coagulation, filtration and chlorination. Alum, Nuchar, ammonium sulfate and chlorine used in purif., chem. cost per mil.gal. being \$3.02. Consumption avgd. 2.5 mgd., equivalent to 79.8 gal. per capita to pop. of 31,135. Filter wash water avgd. 1.26% of total pumpage. 13.1' of water mains per person served. Expenditures in '40 totaled \$173,563.65 (\$5.58 per capita), of which \$75,377.50 was for debt requirements. Revenue \$167,930.47.—*R. E. Thompson.*

**Annual Report, London, Ont., 1940.**

ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 6: 7 (Sept. '41). Data given from 62nd annual rept. of Public Utilities Com. Avg. consumption by estd. pop. of 77,369 was 6.14 mil.gal., equivalent to 79.3 gal. per capita. 24,525 services, all metered, through which passes 76.2% of pumpage, and 203 mi. of mains, equivalent to 43.8' per service or 13.9' per capita. Rates per 100 cu.ft. are: first 200 cu.ft., 66½¢; next 50,000 cu.ft., 11¢; remainder, 7¢. Min. bi-monthly bill \$1.11. 10% discount allowed for prompt payment. Rental charged for meters of 1" or over. Rates outside city double city rates. Avg. domestic bill 99¢ per mo. Surplus on year's operation \$87,255.40. Hydrant rental \$18.—*R. E. Thompson.*

**Annual Report, Timmins, Ont., 1940.**

ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 7: 9 (Sept. '41). Supply works owned by Hollinger Mines and distr. system by municipality. Water pumped by company and sold to city at cost. Treatment consists of chlorination only. Consumption avgd. 51.5 gpd. per capita to pop. of 28,630. Avg. cost of water purchased 5.49¢ and avg. revenue 17.48¢ per 1,000 gal., giving net surplus of \$4,745.44 for yr. Hydrant rental \$38. Hydrant maint. costs avgd. \$11.93 and meter reading costs (about 5% of services are metered) \$2.80 per meter.—*R. E. Thompson.*

**Brockville Report, 1940.** ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 8: 11 (Sept. '41). Supply derived from St. Lawrence R. and chlorinated. 3,036 consumers and military camp of

2,000 also supplied. Pumpage avgs. 2.04 mgd. Revenue avgd. \$11.94 per consumer and operating costs \$7.79. Surplus on year's operation \$7,595.16, after donating \$7,000 to municipal council and omitting one quarterly bill to each consumer. System, valued at \$428,918, free from debt.—*R. E. Thompson.*

**Ottawa Report, 1940.** ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 9: 12 (Dec. '41). Water drawn from Ottawa R. and purified by gravity mechanical filtration and chlorination. Pop. supplied 165,116, 150,277 being within city limits. 32,458 services, 2,383 meters and 1,968 hydrants. Pumpage avgd. 18.5 mgd., equivalent to 112 gal. per capita. Avg. chemical dosages: alum, 2.49 gpg.; lime, 0.8 gpg.; chlorine, 3.48 lb. per mil.gal.; activated carbon, 3,198 lb. total. Avg. rate of filtration 63.7 mgd., while wash water avgd. 1.56% of filtered water. Filter runs avgd. 77 hr. Surplus on yr.'s operation \$11,790.93.—*R. E. Thompson.*

**Annual Report, Dorval, Quebec, 1940.**

ANON. W.W. Inf. Exch., Can. Sec. A.W.W.A. 4: E: 10: 14 (Dec. '41). Supply drawn from Ottawa R. and purified by filtration and chlorination. Consumption avgd. 240 gpd. per capita by pop. of 2,000. 82 fire hydrants and 540 services. Avg. water bill \$26.46 per service or \$7.14 per capita. Alum used avgd. 2.7 gpg. and wash water 4.6% of water filtered. Avg. cost of filter operation \$22.65 per mil. gal., cost for alum and chlorine alone being \$6.90 per mil. gal.—*R. E. Thompson.*

**FOREIGN WATER SUPPLIES—GENERAL****Trinidad Central Water Supply Scheme.**

ANON. Civ. Eng. (Br.) 36: 457 (May '41). Trinidad lies about 16 mi. east of Venezuela. Avg. length of island 50 mi., breadth 37 mi. and area 1,862 sq.mi. Pop. in '31, 390,000. In '27 attempt made to overcome conditions causing water shortage in Port of Spain, San Fernandon, and country dists. Quare Valley, in northern range of hills, chosen

for impounding scheme. Estd. that with catchment area of 3,571 acres and reservoir of 1.05 billion gal. (Imp.) capac., yield of 5.2 mgd. (Imp.) could safely be expected during 3-yr. drought cycle. Earth dam constructed was 65' high, with max. depth of core wall 30' below stream bed. During constr., normal river flow passed through 24" pipe under dam; flood flows diverted

through tunnel driven in western haunch of dam. Reservoir area covered by dense jungle contg. large no. of trees of great size. Several clearances of vegetation had to be made before impounding. Areas which contained wet peat dug out; limestone outcrops and river channel near dam covered by well rammed clay. Soon after impounding commenced water changed from sparkling wholesome liquid to one which smelled and was almost unusable. Filters found to contain much sediment and mud-balling quickly took place. Supplementary supply of water provided for filter washing. The 70 mi. of trunk mains almost entirely of steel, bitumen-lined, and coated with bitumized hessian in usual manner. Ten service reservoirs, some of steel and some of concrete, used. Steel reservoirs placed where foundation was sand. Demand for extensions so insistent that they have been made from Siparia to Erin, Rio Claro to Moruga, and others are in course of constr. to Fyzabad and to Mayaro. Separate schemes under constr. for Cedros, La Brea, and Point Fortin.—*H. E. Babbitt.*

**Water-Supply Development in a South American City.** SAMUEL L. HOLLOPETER. *Am. City.* **56:** 6: 59 (June '41). Pop. of Barranquilla, Colombia, increased from 80,000 in '25 to 165,000 today. Prior to '29 when filtration plant completed, water from Magdalena R. (turbidity 300 to 800 ppm.) used raw. Water now treated in 8-mgd. plant consisting of 3 low-lift pumps, 4 mixing basins with flocculators, 2 coagulation basins, 4 rapid sand filters, clear well, wash water tank, feeders, chlorinators, 3 high-lift pumps and 2 concrete reservoirs. Capac. of plant currently being doubled. Equip. from U.S. represented by such names as Cameron, DeLaval, Westinghouse, Worthington, Roberts, Ludlow and Wallace & Tiernan.—*F. J. Maier.*

**The Water Supply of Rome.** G. TIAN. *Dtsch. Wasserw. (Ger.)* **35:** 71: 100 ('40); *Zbl. Ges. Hyg. (Ger.)* **46:** 447 ('40). Water supply of ancient Rome collected in surrounding hills and carried to city in open aqueducts. In recent yr. Vergine aqueduct reconstructed and

used for carrying drinking water. Less pure water used for industry and ornamental fountains. Greater part of drinking water supply obtained from Marcia springs, north of Tivoli; carried in masonry aqueduct to Tivoli, and then to Rome through iron pipes. Temp. of water is about 9°C. at all times of year. From all sources, total of 400 l. per head per day supplied to pop. of about 1,200,000.—*W.P.R.*

**Scalby's New Water Supply.** ANON. *SURVEYOR. (Br.)* **99:** 274 (Apr. 18, '41). New water supply for urban dist. of Scalby, Yorks, inaugurated recently. Works comprised sinking of borehole, erection of pumping station, pumping machinery, elec. generating plant, new reservoir, rising and trunk main, and other appurtenant works. During past 10 yr. consumption, entirely domestic, risen to 96,282 gpd. (Imp.). Estd. cost of works £12,600.—*H. E. Babbitt.*

**Water on the Witwatersrand.** ANON. *Wtr. & Wtr. Eng. (Br.)* **53:** 57 (Mar. '41). Avg. quant. of water sold to consumers increased from 11.1 mgd. (Imp.) in '20 to double that amt. in '35. Estd. avg. for '41, 51.5 mgd. (Imp.). Board has completed works capable of supplying 68.0 mgd. On these schemes approx. £4,000,000 spent.—*H. E. Babbitt.*

**Wimmera-Mallee Water Supply Developments.** ANON. *Commonwealth Engr. (Australia)* **28:** 147 ('40). To supplement water supply of dist., area of 11,000 sq.mi. in northwestern Victoria, Australia, decided to utilize water from Glenelg R., by constructing diversion channel from storage dam on Glenelg R. through Barton's Swamp to Taylor's Lake, distance of about 50 mi. Dam to be built at head of channel. Storage reservoir will have area of water surface at high water of 19,750 acres and capac. of 264,000 acre-ft. Total cost of works estimated at £874,000. Map given showing existing and proposed channels and storage reservoirs.—*W.P.R.*

**Water Supply in Cyprus.** C. RAE-BURN. *Wtr. & Wtr. Eng. (Br.)* **43:** 148, 166 (May, June '41) Water supply on

island of Cyprus dependent on rainfall and great springs that issue from limestone of Trypa formation. From early days, springs used for irrigation and ancient wells and aqueducts common. After British occupation, in 1878, coastal fringes considerably developed for underground water. In '37 not many new sources remained to be discovered. For increasing water supply, main body of opinion favors work for retention of winter water, particularly in hills. Dams in hills are panacea. Increased output of water might be secured by boring or tunneling in Kyrean Hills, where, if springs are truly artesian, they derive their water from lofty Anatolian range across narrow Karamanian Sea. In Mesaoria area, sub-parallel to present rivers, is an ancient buried river system. Coarser gravels of river bed yield water freely. Geophysical work indicates where productive holes may be sited. Not possible to advocate deep drilling in Mesaoria. Rainfall of Cyprus occurs mainly from Oct. to Mar. Considerable snowfall. Rivers not perennial streams. Rain once past, water soon disappears leaving bed bouldery and parched, so to continue for months. Constr. of water works in rivers controlled by Comr. General opinion throughout island that large quants. of water lost to sea by surface flow. Doubtful if preventable losses serious. Flooding of destructive character practically ceased in western Mesaoria area. Medicott's diversion project proposed taking flow of Akacha R. in excess of 100 cusecs and delivering it through tunnel into tributary of Merka. Cost of project estimated at £135,000. Rivers from Morphu along bay towards Xeros have lower reaches in sediments and those not already tapped by infiltration galleries may be dealt with by subsurface dams. This is an impervious septum constructed across pervious gravels and keyed to impervious rocks at sides and bottom. Relatively cheap to construct as it is supported and protected by gravels. Eastern Mesaoria reservoirs, constructed 40 yr. ago, are only large-scale impounding works in Cyprus. Their failure to provide expected water attributed to unreliability of Cyprus

rainfall. Impounding schemes in hills do not store water in proportion to annual rainfall because of constant loss by evaporation, percolation, and transpiration. Present state of reservoirs melancholy one. Three works completed were Akhyritou, Koukolia, and Syngrasi reservoirs with combined storage vol. of 1,270 million cu.ft. Gradually more and more of reservoir beds have come under cultivation and spillways have been cut down so that attempt at storage has ceased. "Chain-of-wells" is sort of infiltration gallery extended by conduit at less inclination than land surface above it, which thus eventually allows water to flow at surface. These are relatively cheap and within power of villagers to construct and maintain. These structures most common in western Mesaoria and some reach considerable length. When properly covered and protected good bacterial anals. may be obtained in their waters. Privately-owned irrigation project in Paphos dist. draws water from Ezuza R. No works provided to control flow or to ensure that no water flows to waste. Measure of water in all towns in massoura, subdivided into four saccoraphia which denotes size of opening into aqueduct or main. Unit does not give any definite quant. of water but merely amt. of water which will pass through opening, vol. of water delivered varying according to quant. in mains. Massoura has been reckoned to supply between  $1\frac{1}{2}$  and 4 gpm. (Imp.). With exception of two towns, flow diminishes toward end of summer so that supply has to be shut off during certain hours daily. Usual house supply consists of one saccorphi, giving about 32 gpd. (Imp.) per head. In Nicosia, five private companies supply water from 45 to 309 saccorphi daily, irrigation company delivering 42,000 gpd. (Imp.) Larnaca obtains supply from chain-of-wells approx. 2 mi. in length, constructed in 1745 A.D. by Abu Bekir. Min. supply estd. at 980,000 gpd. (Imp.), giving avg. of 80 gpd. (Imp.) per head. Limasol supply comes from: (1) chain-of-wells in Garyllis R.; (2) overflow from spring; and (3) chain-of-wells west of town. Spring and one chain supply

dry-season flow of 52,800 gpd. (Imp.). In Famagusta there are four sources, including spring and four wells. Spring water conveyed to town by old masonry aqueduct said to be Venetian. For Paphos flow from springs and chain-of-wells diminishes during summer, necessitating shutting off supply for certain hours daily. For Kyrenia flow from all underground sources gives total min. supply of 38 gpd. (Imp.) per capita for pop. of 2,279.—*H. E. Babbitt.*

#### Water Scheme Held Up in South Africa.

ANON. Wtr. & Wtr. Eng. (Br.) **43**: 214 (Midsummer '41) Great Britain's ban on export of steel pipe and other such products causing serious delay to Port Elizabeth's Kromme R. water scheme. Port Elizabeth City Council announced that negotiations have been opened with view to obtaining necessary steel pipe from Canada and U.S. Feared that in many other water schemes in South Africa in which it is desired to use British steel pipe, provision will now have to be made to obtain them from Canada and U.S.—need that is regretted by many engrs. in Union.—*H. E. Babbitt.*

#### The Water Supply of Salisbury, S. Rhodesia.

W. J. JARVIS. Engineering (Br.) **150**: 257, 266 ('40). Up to '11, water supply drawn from wells. In '11 Cleveland dam constructed on Makabusi R. and water treated in primary filters followed by slow sand filters. Difficulties due to deficient rainfall occurred frequently and water had to be obtained from boreholes. Further supply, from Prince Edward reservoir on Hunyani R. brought into service in '29. Pumping plant and treatment works for this supply enlarged. Pumps now capable of delivering  $2\frac{1}{2}$  mgd., and treatment plant comprises mixers, flocculators, and settling tanks to deal with 3 mgd., and rapid sand filters capable of treating 2 mgd. Amt. of water required still increasing rapidly. Difficulties in filter plant for Cleveland dam supply caused in '37 by algal growths and water in reservoir became stagnant owing to rotting of vegetable matter. Not possible to empty and clean out reservoir, which was treated with permanganate of potash

and copper sulfate. Slow sand filters emptied and converted into settling tanks, and water aerated to remove gases by pumping it into air, and treated with alumina to effect flocculation, potassium permanganate or chloride of lime to oxidize vegetable matter, active carbon to remove taste and odor, and copper sulfate to prevent growths of algae in plant and distr. system. Rapid sand filters added to plant emptied and sand washed. This found necessary after 3 to 4 weeks' operation, as usual stirring and back-washing did not remove fine vegetable matter. Lime, ammonia, and chlorine added after filtration. Further improvements to plant planned.—*W.P.R.*

#### Water Supply Investigation in the Nyasaland Protectorate.

ANON. Geol. Survey Dept., Nyasaland Protectorate, Progress Rept. No. 8 ('38); Wtr. & Wtr. Eng. (Br.) **42**: 50 ('40). In '38, 6 boreholes completed and 1 abandoned; avg. min. daily yield of productive boreholes, 35,507 gal. 57 wells completed and 2 improved; min. daily yield, 4,103 gal. Instructions to fill in all abandoned shafts issued. Samples of borehole and well waters analyzed at Imperial Inst. Water from hot spring near Liwonde found to be very soft, contg. approx. 430 ppm. sodium carbonate and sulfate. Regarded suitable for domestic supply; content of mineral salts not high enough for marked medicinal value. Geology and hydrology of Dowa, Lilongwe, and South Nyasa districts as they concern sinking of boreholes and wells, and yield of water therefrom, described.—*W.P.R.*

#### Baghdad District Water Board.

ANON. Wtr. & Wtr. Eng. (Br.) **43**: 120 (Apr. '41). Administrative report of Baghdad Water Board for yr. ended Mar. 31, '40 gives particulars of Board's extension of supply to Adhamiya, main event of period. Main extensions reached new high record. Scale of existing rates remained unchanged except for introduction of special low rates for poorer class houses. Total amt. of water pumped, in millions of cu.m., was: at Sarrafiya, 5.7; Shalchiya, 2.08; Karrada, 0.38; and Ad-

hamiya, 0.33. Chlorine dose increased from 0.4 to 0.5 ppm. in June, and to 1.0 ppm. in mid-Aug., reduced to 0.5 ppm. in mid-Sept. No serious interruptions of supply, but shortage of pressure reported at various places. As result of treatment, avg. colony count reduced to 16.6 per ml., and in 98% of samples *Esch. coli* absent from 100 ml. Mains for irrigation extended 8,346 m. Year '40 regarded as unfortunate so far as

leaks concerned. Removal of old service pipes continued. Coated steel pipe used for about 3½ yr. Copper pipe used for service pipe since '36 and has proved generally satisfactory. Warming effect of ground resulted in water in house tap being on avg. 6°F. warmer than river. Present rate of growth of consumption indicates necessity of extension of Sarrafiya filtration works few years hence.—H. E. Babbitt.

### BOILER FEED WATER

#### 25 Years Development in Water Service.

ANON. Ry. Eng. & Maint. **37**: 409 ('41). Longer and faster engine runs, higher boiler pressure, and large engine tanks have drastically changed railroad water requirements during past 25 yr. Fewer water station stops have required dependable pumping, storage and delivery units. Water softening plants have increased from 480 in '16 to 3,250 in '41. Many wayside plants in use and most waters now receive some form of treatment to reduce incrustation and corrosion.—R. C. Bardwell.

#### Feed Water Control in Minnesota and Ontario Paper Mill. H. E. EINERT.

Paper Tr. J. **112**: 14: 31 ('41). Surveys conducted which revealed high O and low pH in feed water and excessive mud and algae in zeolite softeners. By improving de-aeration, recirculating boiler water, installation of sand filters ahead of zeolites and application of supplemental treatment, source of trouble removed. Control system established frequently to check all constituents pertinent to feed water and boiler water to insure continuity of operation and low treating costs described.—C.A.

#### Notes on Boiler Feed Water Treatment.

A. H. PRAEGER. Proc. Qd. Soc. Sugar Cane Tech. **10**: 31 ('39). Author reviews methods and problems of treatment of boiler feed water, especially for sugar factories, in light of recent research. Presence of D.O. or acidity in water prevents maint. of protective film of hydrogen over metal. Make-up water can be sufficiently de-aerated before

being mixed with condensate water for use as boiler feed by heating it, by introduction of low-pressure steam, almost to bp. To maint. alk. conditions in boiler, accidental entry of sugar should be prevented. pH values between 9 and 10 generally recommended as rate of corrosion reduced and alky. not sufficient to induce caustic embrittlement. Embrittlement can be avoided with most certainty by maintg. sulfate-alky. ratio greater than 2:1. Recent work suggests that other agents such as phosphates or salts capable of acting as oxidizing agents more effective inhibitors. Formation of scale may be prevented by softening feed water and by sufficient blowing down. Boiler water can be conditioned with carbonates or phosphates, producing sludge-forming in place of scale-forming salts, or with colloids such as tannin, dextrin, etc., which act by absorption and coagulation of scale-forming salts. Oil present in boiler water, leading to retardation of transfer of heat and overheating of the metal, may be removed by mechanical separation, or, if oil is emulsified, by coagulation, by elec. or chem. treatment.—W.P.R.

#### The Soda-Lime Process for Feed Water Treatment. N. SMITH. Intern. Sugar

J. **43**: 208 ('41). Reduction of 80% in hardness of feed water obtained by soda-lime process. Twice calcd. quant. of reagents recommended together with 1-2 oz. sodium aluminate per 1,000 gal. water. Temp. of 40° to 60° gives more rapid action. Filtration of treated water through thick layer of sludge gives optically clear water.—C.A.

**The Contribution of Water Conditioning to Steam Generation.** E. P. PART-  
RIDGE AND A. C. PURDY. *Trans. A.I.C.E.* **35**: 169 ('39). Summarizes advances in design of boilers during past 20 yr. Developments in conditioning of boiler water discussed. Before development of high-pressure boilers, scales formed consisted chiefly of calcium sulfate, calcium carbonate, and calcium and magnesium silicates, which formed insulating layers and caused overheating of metal. Methods of control available were distn. or softening of feed water or addn. of boiler compds., but these did not afford complete protection. Use of phosphates for conditioning boiler water increased rapidly after '24. Softening of feed water desirable except when hardness of raw water very low; recent advances in softening include use of organic base-exchange materials, and use of sodium orthophosphate and caustic soda as precipitants in hot-water softener. As pressures in boilers and rate of heat input increased, trouble due to sodium aluminum silicate scale developed. This may be controlled by eliminating alumina or silica from feed water or by reducing rate of heat input. Avoidance of scale may lead to corrosion unless oxygen removed; usually done by de-aerating feed water and removing last traces of oxygen by addn. of sodium sulfite. Question of embrittlement debated since '18, and causes and methods of control still under discussion. For time, thought that regulation of sulfate-alky. ratio in boiler water would control embrittlement, but cracking has occurred when recommended ratio maintd. As scale formation and corrosion controlled, "carry-over" and foaming caused more trouble in h-p. boilers. Carry-over of small droplets can largely be prevented by mech. means. Reliable anti-foam material not yet developed. Special problems involved in conditioning water for marine boilers and for locomotives discussed. Development of chem. anal. used in boiler water conditioning outlined.—W.P.R.

**Co-ordination of Water Conditioning With Operating Problems.** R. E. HALL AND C. E. KAUFMAN. *Power Plant*

*Eng.* **45**: 61 (Sept. '41). *I.* Special treatment necessary to meet demands of varying feed water limits of modern high pressure boilers. Alky. control for protective film and oxygen removal necessary for corrosion prevention. Embrittlement control discussed (cf. *Jour. A.W.W.A.* **32**: 702 (1940)). *Ibid.* **45**: 59 (Oct. '41). *II.* Prevention of deposits from water discussed, with special emphasis on relative concn. of salts in feed water and economical justification of only partial treatment of waters for specific boiler conditions.—T. E. Larson.

**Carbonate Conditioning of Boiler Water. Limitations Imposed by the Carbonate-Sulfate-Hydroxyl Balance.** W. F. GERARD. *J. Soc. Chem. Ind.* **60**: 92 ('41). Prevention of sulfate scale in steam boilers by means of  $\text{Na}_2\text{CO}_3$  involves maint. of certain min. ratios carbonate/sulfate in boiler  $\text{H}_2\text{O}$ .  $\text{Na}_2\text{CO}_3$ , however, is unstable in soln. at elevated temps. and NaOH produced. Presence of free NaOH in feed  $\text{H}_2\text{O}$  advocated to establish pH value high enough to prevent ordinary corrosion in distr. systems; this adds substantially to OH concn. in boiler  $\text{H}_2\text{O}$ . NaOH known to play some part in causing embrittlement of ferrous metals and  $\text{Na}_2\text{SO}_4$  proposed for use as inhibitor. Since rate of conversion of  $\text{Na}_2\text{CO}_3$  into NaOH progressive with rise in temp. and because ratio carbonate/sulfate required to prevent  $\text{CaSO}_4$  scale likewise appreciates, evident that for any given boiler pressure there is a critical balance carbonate-sulfate-hydroxyl. These values now defined by application of triangle diagram. Limitations of carbonate conditioning shown to be serious even at lower operating pressures.—C.A.

**How an Industrial Topping Plant Treats Feed Water.** H. FLYNN AND J. D. YODER. *Power*. **85**: 554 (Aug. '41). Steam from 300,000 lb. per hr. boilers delivered to turbine-generators at 600 lb., 715°F. Feed water is 70-75% makeup from Neches R. of low hardness and continuous high turbidity. Treatment consists of coagulation with 35-85 ppm. alum at pH 5.7-6.8, neutraliza-

tion to pH 7, zeolite softening to 2 ppm., alky. reduction and sulfate-alky. ratio maintd. by  $H_2SO_4$ , de-aeration to .005 ppm.  $O_2$ , addn. of 2.5 ppm.  $Na_2SO_3$  and maintg. pH of 8.8.—*T. E. Larson.*

**Treating Boiler Feed Water Chemically.** *Symposium.* Proc. Master Boilermakers Assn. ('40). p. 218. C. A. STUEBBEN: Texas Pacific Ry. has 44 water treating plants between New Orleans, La., and El Paso, Tex. Despite 34% increase in boiler pressure life of flues and fire boxes materially increased. JOHN P. POWERS: Chem. testing equip. now available standardized and calibrated to give sufficient accuracy for making boiler water check tests from locomotives at terminals to assist in controlling treatment and amt. of blowdowns. Photographs and description given. F. B. HORTSMANN: Review of progress in field. E. E. OWENS *et al.*: Replies to questionnaire indicate most railroads are using some form of boiler water treatment which has materially increased useful life of material and reduced pitting and corrosion. B. C. KING: Supplemental treatment with org. materials in addn. to lime-soda treatment, permitted reduction in percentage alky. required to maint. good boiler conditions and also increased critical foaming concn. which permitted longer runs with less foaming trouble between St. Paul, Minn., and Jamestown, N.D. Automatic continuous blowdown further improved conditions.—*R. C. Bardwell.*

**Boiler Compounds and Colloids.** F. J. MATTHEWS. *Brewing Tr. Rev.* **53**: 266 ('39). Use of boiler compds. often essential complementary process to normal external water softening, and, in some cases, org. materials superior to inorg. reagents. Properly compounded mixt. will contain inorg. reagents such as alkalies or phosphates, whose rôle is to reduce hardness of water and thus throw scale-forming matter out of soln., and colloidal material such as tannin which prevents adherence of scale-forming deposits to heating surfaces and also takes care of any excess hardness that inorg. materials cannot counter. Guiding principles for selection of amt. and

kind of reagents for various types of water discussed.—*C.A.*

**What Is Excess Treatment?** R. C. BARDWELL AND C. R. KNOWLES. *Ry. Eng. & Maint.* **37**: 288 ('41). Excess treatment with soda ash or its equivalent above that required to neutralize non-carbonate hardness considered necessary in boiler water treatment to maintain sodium alky. amtg. to at least 15% of total dissolved solids to maint. conditions free from adherent scale deposits and corrosion.—*R. C. Bardwell.*

**Boiler Water Concentration Can Be Too Low.** W. L. STARKWEATHER. *Power.* **85**: 724 ('41). Tests showed that boiler water concn. below optimum range may increase carry-over in steam. In particular plant, optimum range was 1,100-1,335 ppm., except for unexplained periodic changes where it was 850-1050 ppm.—*T. E. Larson.*

**Embrittlement Detector Testing on Boilers.** W. C. SCHROEDER, A. A. BERK AND C. K. STODDARD. *Power Plant Eng.* **45**: 76 (Aug. '41). Description given of embrittlement detector applicable by direct attachment to boiler or in lab. Tests on stationary and locomotive boilers with this detector showed that sodium sulfate did not stop cracking of specimens. Sodium phosphate, 500 ppm. (in absence of sodium hydroxide), quebracho (a tanning agent—extract from wood of quebracho tree) in maintd. concn. of 23-40 ppm., and sodium nitrate (100-200 ppm.) have each given satisfactory results.—*T. E. Larson.*

**Silicic Acid and Its Meaning in High Pressure Boiler Operation.** A. SPLITTGERBER. *Wasser u. Abwas. (Ger.)* **38**: 58 ('40). Silica forms scale in steam boilers and volatilizes with superheated steam to give deposits on turbine blades. Silica can be removed from boiler feed water by magnesite filters (acid soln.), by adsorption on  $Mg(OH)_2$  pptd. with NaOH and by  $NaAlO_2$ .  $Fe_2(SO_4)_3$  gives better results than  $Al_2(SO_4)_3$ . Efficient silica removal accomplished by combined action of magnesia and Fe or Al salts.

Silica also removed by electrolytically produced flocculating agent.—*C.A.*

**Solution of Silicic Acid in Waters of Different Acidities.** L. W. HAASE AND P. V. DARDANELLI. *Wasser u. Abwas.* (Ger.) **38**: 102 ('40). Silica dissolved from sand filters by hot and cold natural or treated waters. Magno filters adsorb silica and are to be preferred in boiler feed water treatment.—*C.A.*

**Removal of Dissolved Gases From Boiler Feed Water.** ARTHUR E. KITTEDGE. *Proc. Midwest Power Conf.* **4**: 156 ('41). Removal of  $\text{NH}_3$ ,  $\text{CO}_2$  and O from boiler feed water by de-aerator takes place in 2 stages. Eff. of first stage governed by surface tension of liquid and pressure on system. In tray de-aerators, eff. of second stage controlled by individual tray eff., no. of layers of trays and viscosity of water. Jet atomizing de-aerators described.  $\text{NH}_3$  and  $\text{CO}_2$  can be removed only by addn. of base and acid, resp. Abs. zero O content not logical and O guarantee values should be set at lowest values within limits of reliable detn.—*C.A.*

**Degasification of Steam Samples for Conductivity Tests.** P. B. PLACE. *Combustion*. **13**: 2: 31 (Aug. '41). Summary of available methods and apparatus for degasification of steam samples given. Continuous flow degasifiers can

reduce  $\text{CO}_2$  to extent where conductivity error negligible. High partial pressure and high conductivity of ammonia makes it very difficult to remove to point where conductivity error negligible. Correction can be made to conductivity for ammonia left in sample.—*T. E. Larson.*

**Oil in Boiler Water.** ANON. *J. Am. Chem. Soc.—News Ed.* **19**: 1386 (Nov. 25, '41). To det. oil in boiler feed water, add latter to 2" depth in clean test tube and shake short period. Oil globules on surface indicate oil in feed water. Absence of globules indicate amt. of oil small. Condensed exhaust from reciprocating engines and pumps frequently wasted because of oil or grease contain. May cause foaming and priming, overheated boiler tubes, and corrosion. Emulsified oil must be coagulated to remove by filtration. Aluminum sulfate and caustic soda used. Filter operation simple. Contam'd. water enters filter at top, leaves from lower connection. Influent passes through adjustable orifice of sufficient resistance to divert small proportional amt. through coagulant tank where it becomes sat'd. with alum to filter side of orifice at rate proportional to rate of flow through adjustable orifice. With sufficient coagulant, filter gives crystal clear effluent. When pressure loss through filter excessive, filter should be cut from service and backwashed.—*Ralph E. Noble.*



## Graphical Symbols for Use on Drawings

WITH the organization of the Sectional Committee on Standards for Drawings and Drafting Room Practice in 1926, six sub-committees were appointed to develop the various phases of this project. To Sub-Committee No. 6 was assigned the development of a set of standard graphical symbols for use on drawings. At its December 1928 meeting, the committee reviewed a number of suggested series of symbols including: (1) those proposed by the American Society of Heating and Ventilating Engineers in 1925, and (2) those proposed by the National Association of Master Plumbers of the United States in 1926, and approved in revised form in 1929.

In the preparation of the tentative proposal the committee drew on material from the publications of various organizations. Copies of this draft were distributed broadly to industry for criticism and comment in July 1932. After a thorough study the sub-committee made its report to the Sectional Committee. Upon approval by this committee the standard was submitted for approval to the sponsor bodies and the American Standards Association. It received the designation of American Standard in November 1935, with the serial number Z14.2—1935.

During the last stages of this activity a number of interested groups including the ASA Electrical Standards Committee requested that this project be broadened. Accordingly, in November 1933, the American Standards Association called a conference to which were invited representatives of the sponsors of the Sectional Committee on Standardization of Letter Symbols and Abbreviations for Science and Engineering (Z10) and the Sectional Committee on Standards for Drawings and Drafting Room Practice (Z14), respectively, together with officers of these sectional committees and of the E.S.C. Committee on Scopes, the technical advisers to the U.S. National Committee of the International Electrotechnical Commission on Letter Symbols, and certain interested individuals.

Abstracted from "American Standard for Graphical Symbols for Use on Drawings in Mechanical Engineering. (ASA Z32.2—1941)," published by The American Society of Mechanical Engineers, New York, price 50 cents. Symbols Nos. 173 through 219, relating to heating and ventilating and ductwork, and Nos. 280 through 310, relating to refrigerating, have been omitted.

After a frank discussion of the activities of Sectional Committee Z10 and Z14 and the desired further development of the subject of graphical symbols and abbreviations for use on drawings, it was agreed that all of the activity on graphical symbols should be concentrated in a new sectional committee sponsored by the American Institute of Electrical Engineers and The American Society of Mechanical Engineers, the committee to be known as Z32 on Standardization of Graphical Symbols and Abbreviations for Use on Drawings. It was further agreed that the projects on graphical symbols so far completed or in progress by Sectional Committees Z10 and Z14 should be transferred to Z32 after the present plans for publication had been consummated. These agreements were transmitted to the sponsor societies of the two committees in January 1934. Their approval was given and the recommendations were passed on to the ASA which authorized this realignment in June 1935.

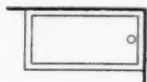
To bring the existing standard in line with the best current practice, a revision of Z14.2—1935 was begun by Sub-Committee No. 1 and its subgroups, providing for the addition of symbols on air-conditioning, sprinklers, pneumatic tubes, ductwork, refrigerating, and welding. The welding symbols not included in this standard, but printed in it as an appendix, were developed by the Symbols Committee of the American Welding Society, and the refrigerating symbols (not included in this presentation) by a similar committee of the Air-Conditioning and Refrigerating Machinery Association.

A preliminary draft of the new material was first presented to the members of the sectional committee at a meeting held in December 1939. Slight changes in the welding symbols and the footnotes applying to them (not finally approved—printed for advance information only) were made subsequent to that meeting. The revised proposal now known as Z32 was approved by letter ballot vote of the sectional committee, and, following approval by the sponsor bodies, was presented to the American Standards Association with recommendation for approval as an American Standard. This designation was given in November 1941.

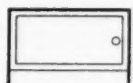
# Graphical Symbols for Use on Drawings

## Plumbing

1 Corner Bath



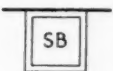
2 Recessed Bath



3 Roll Rim Bath



4 Sitz Bath



5 Foot Bath



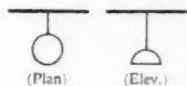
6 Bidet



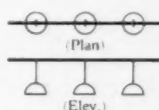
7 Shower Stall



8 Shower Head



9 Overhead Gang Shower



10 Pedestal Lavatory



11 Wall Lavatory



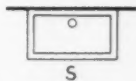
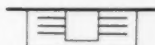
12 Corner Lavatory

13 Manicure Lavatory  
Medical Lavatory

14 Dental Lavatory



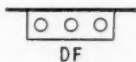
15 Plain Kitchen Sink

16 Kitchen Sink  
R & L Drain Board

Graphical Symbols for Use on Drawings		<i>Plumbing</i>	
17 Kitchen Sink L. H. Drain Board		25 Water Closet (No Tank)	
18 Combination Sink and Dishwasher		26 Urinal (Pedestal Type)	
19 Combination Sink and Laundry Tray		27 Urinal (Wall Type)	
20 Service Sink		28 Urinal (Corner Type)	
21 Wash Sink (Wall Type)		29 Urinal (Stall Type)	
22 Wash Sink		30 Urinal (Trough Type)	
23 Laundry Tray		31 Drinking Fountain (Pedestal Type)	
24 Water Closet (Low Tank)		32 Drinking Fountain (Wall Type)	

# Graphical Symbols for Use on Drawings

## Plumbing

33 Drinking Fountain  
(Trough Type)

41 Drain



34 Hot Water Tank



42 Grease Separator



35 Water Heater



43 Oil Separator



36 Meter



44 Cleanout



37 Hose Rack



45 Garage Drain



38 Hose Faucet

46 Floor Drain With  
Backwater Valve

39 Gas Outlet



47 Roof Sump



40 Vacuum Outlet



# Graphical Symbols for Use on Drawings

*Piping*

## HEATING

60 High Pressure Steam	
61 Medium Pressure Steam	
62 Low Pressure Steam	
63 High Pressure Return	
64 Medium Pressure Return	
65 Low Pressure Return	
66 Boiler Blow Off	
67 Condensate or Vacuum Pump Discharge	
68 Feedwater Pump Discharge	
69 Make Up Water	
70 Air Relief Line	
71 Fuel Oil Flow	
72 Fuel Oil Return	
73 Fuel Oil Tank Vent	
74 Compressed Air	
75 Hot Water Heating Supply	
76 Hot Water Heating Return	

## AIR CONDITIONING

80 Refrigerant Discharge	
81 Refrigerant Suction	
82 Condenser Water Flow	
83 Condenser Water Return	
84 Circulating Chilled or Hot Water Flow	
85 Circulating Chilled or Hot Water Return	
86 Make Up Water	
87 Humidification Line	
88 Drain	
89 Brine Supply	
90 Brine Return	

# Graphical Symbols for Use on Drawings

*Piping*

## PLUMBING

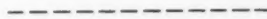
100 Soil, Waste or Leader (Above Grade)



101 Soil, Waste or Leader (Below Grade)



102 Vent



103 Cold Water



104 Hot Water



105 Hot Water Return



106 Fire Line



107 Gas



108 Acid Waste



109 Drinking Water Flow



110 Drinking Water Return



111 Vacuum Cleaning

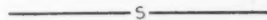


112 Compressed Air



## SPRINKLERS

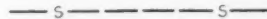
120 Main Supplies



121 Branch and Head



122 Drain



## PNEUMATIC TUBES

123 Tube Runs






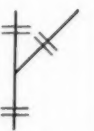
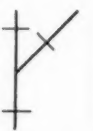








































Graphical Symbols for Use on Drawings		<i>Pipe Fittings and Valves</i>				
		Flanged	Screwed	Bell and Spigot	Welded	Soldered
130 Joint						
131 Elbow 90 deg						
132 Elbow 45 deg						
133 Elbow Turned Up						
134 Elbow Turned Down						
135 Elbow Long Radius						
136 Side Outlet Elbow Outlet Down						
137 Side Outlet Elbow Outlet Up						
138 Base Elbow						
139 Double Branch Elbow						

# Graphical Symbols for Use on Drawings





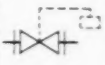
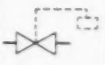

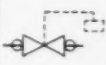






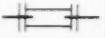

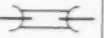






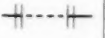







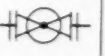








## *Pipe Fittings and Valves*

	Flanged	Screwed	Bell and Spigot	Welded	Soldered
140 Single Sweep Tee					
141 Double Sweep Tee					
142 Reducing Elbow					
143 Tee					
144 Tee—Outlet Up					
145 Tee—Outlet Down					
146 Side Outlet Tee Outlet Up					
147 Side Outlet Tee Outlet Down					
148 Cross					
149 Reducer, Concentric					

Graphical Symbols for Use on Drawings		<i>Pipe Fittings and Valves</i>				
		Flanged	Screwed	Bell and Spigot	Welded	Soldered
150 Reducer, Eccentric						
151 Lateral						
152 Gate Valve Elevation (See 169)						
153 Globe Valve Elevation (See 170)						
154 Angle Gate Valve Elevation (See 171)						
155 Angle Globe Valve Elevation (See 172)						
156 Check Valve						
157 Angle Check Valve						
158 Stop Cock						
159 Safety Valve						

# Graphical Symbols for Use on Drawings

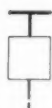
## Pipe Fittings and Valves

	Flanged	Screwed	Bell and Spigot	Welded	Soldered
160 Quick Opening Valve					
161 Float Operating Valve					
162 Motor Operated Gate Valve					
163 Motor Operated Globe Valve					
164 Expansion Joint Flanged					
165 Reducing Flange					
166 Union	(See No. 130)				
167 Sleeve					
168 Bushing					
169 Gate Valve, Plan					
170 Globe Valve, Plan					
171 Angle Gate Valve, Plan					
172 Angle Globe Valve, Plan					

# Graphical Symbols for Use on Drawings

## *Heat-Power Apparatus*

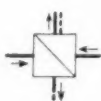
240 Steam Generator  
(Boiler)



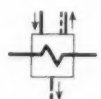
241 Flue Gas Reheater  
(Intermediate Superheater)



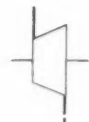
242 Live Steam Superheater



243 Feed Heater With  
Air Outlet



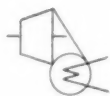
244 Steam Turbine



245 Surface Condenser



246 Condensing Turbine



247 Open Tank



248 Closed Tank



249 Automatic  
Reducing Valve



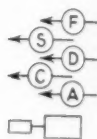
250 Automatic  
By-pass Valve



251 Automatic Valve  
Operated by Governor



252 Pumps  
Boiler Feed  
Service  
Condensate  
Circulating Water  
Air  
Reciprocating



253 Dynamic Pump  
(Air Ejector)



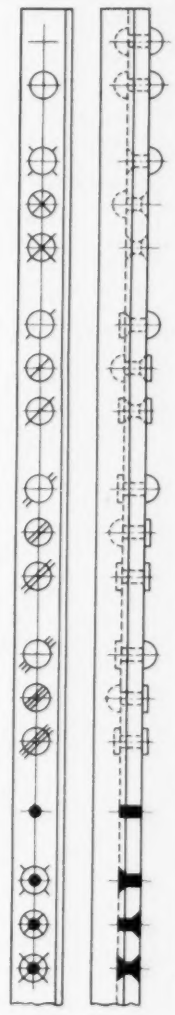
254 Steam Trap



Graphical Symbols  
for Use on Drawings

Conventional Rivets

- 260 Shop Rivets, Two Full Heads
- 261 Shop Rivets, Countersunk and Chipped, Near Side
- 262 Shop Rivets, Countersunk and Chipped, Far Side
- 263 Shop Rivets, Countersunk and Chipped, Both Sides
- 264 Shop Rivets, Countersunk but Not Chipped, Max.  $\frac{1}{8}$  in. High Near Side
- 265 Shop Rivets, Countersunk but Not Chipped, Max.  $\frac{1}{8}$  in. High Far Side
- 266 Shop Rivets, Countersunk but Not Chipped, Max.  $\frac{1}{8}$  in. High Both Sides
- 267 Shop Rivets, Flattened to  $\frac{1}{4}$  in. High for  $\frac{1}{2}$  in. and  $\frac{3}{8}$  in. Rivets Near Side
- 268 Shop Rivets, Flattened to  $\frac{1}{4}$  in. High for  $\frac{1}{2}$  in. and  $\frac{3}{8}$  in. Rivets Far Side
- 269 Shop Rivets, Flattened to  $\frac{1}{4}$  in. High for  $\frac{1}{2}$  in. and  $\frac{3}{8}$  in. Rivets Both Sides
- 270 Shop Rivets, Flattened to  $\frac{3}{8}$  in. High for  $\frac{3}{4}$ ,  $\frac{7}{8}$ , and 1 in. Rivets Near Side
- 271 Shop Rivets, Flattened to  $\frac{3}{8}$  in. High for  $\frac{3}{4}$ ,  $\frac{7}{8}$ , and 1 in. Rivets Far Side
- 272 Shop Rivets, Flattened to  $\frac{3}{8}$  in. High for  $\frac{3}{4}$ ,  $\frac{7}{8}$ , and 1 in. Rivets Both Sides
- 273 Field Rivets, Two Full Heads
- 274 Field Rivets, Countersunk and Chipped, Near Side
- 275 Field Rivets, Countersunk and Chipped, Far Side
- 276 Field Rivets, Countersunk and Chipped, Both Sides



## APPENDIX

Graphical Symbols  
for Use on Drawings

Welding

## ARC AND GAS WELDING

TYPE OF WELD							PLUG & SLOT	FIELD WELD	WELD ALL AROUND	FLUSH
BEAD	FILLET	GROOVE								
		SQUARE	V	BEVEL	U	J				

LOCATION OF WELDS		
ARROW(OR NEAR) SIDE OF JOINT	OTHER(OR FAR) SIDE OF JOINT	BOTH SIDES OF JOINT
<p>FIELD WELD SEE NOTES</p>	<p>INCLUDED ANGLE</p> <p>90°</p> <p>40°</p>	<p>SIZE</p> <p>INCREMENT LENGTH</p> <p>2-5</p> <p>WELD ALL AROUND</p> <p>OFFSET IF STAGGERED</p> <p>PITCH OF INCREMENTS</p>

- 1 The side of the joint to which the arrow points is the arrow (or near) side.
- 2 Both-sides welds of same type are of same size unless otherwise shown.
- 3 Symbols apply between abrupt changes in direction of joint or as dimensioned (except where all around symbol is used).
- 4 All welds are continuous and of user's standard proportions, unless otherwise shown.
- 5 Tail of arrow used for specification reference (tail may be omitted when reference is not used).
- 6 Dimensions of weld sizes, increment lengths and spacings are given in inches.

## RESISTANCE WELDING

TYPE OF WELD				FIELD WELD	WELD ALL AROUND	FLUSH
SPOT	PROJECTION	SEAM	BUTT			
STRENGTH IN UNITS OF 100LBS PER WELD		STRENGTH IN UNITS OF 100LBS PER LINEAR IN.		STRENGTH IN UNITS OF 100LBS PER SQ. IN.		

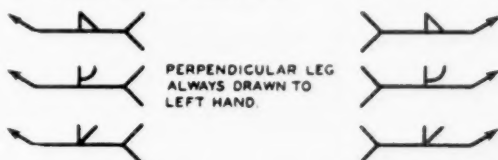
- 1 Symbols apply between abrupt changes in direction of joint, or as dimensioned (except where all around symbol is used).
- 2 Tail or arrow used for specification reference (tail may be omitted when reference is not used).
- 3 All spacings are given in inches.

NOTE: Further information on the use of these symbols will be found in "Welding Symbols and Instructions for Their Use," published by the American Welding Society, New York, price 25 cents.

# Graphical Symbols for Use on Drawings

## Welding

### LOCATION OF WELDING INFORMATION



MANNER OF FINISHING.

INCLUDED ANGLE.

ROOT OPENING.

SIZE (EXCEPT FOR PLUG OR SLOT) OR DETAIL REFERENCE.

OMIT WHEN SPECIFICATION REFERENCE NOT USED.

SPECIFICATION REFERENCE

LENGTH OF WELD OR INCREMENTS OF NON-CONTINUOUS WELDS. (OMIT FOR RESISTANCE WELDS)

PITCH OF NON-CONTINUOUS WELDS

LOCATION OF FINISH SYMBOL WHEN USED.

FLUSH SYMBOL.

BASIC WELD SYMBOL.



ARROW CONNECTING REFERENCE LINE TO JOINT OR TO MEMBER TO BE GROOVED. SIDE OF JOINT TO WHICH ARROW POINTS IS ARROW (OR NEAR) SIDE AND OPPOSITE SIDE IS OTHER (OR FAR) SIDE.

FIELD WELD SYMBOL.

WELD ALL-AROUND SYMBOL.

REFERENCE LINE FOR SHOWING WELD LOCATION.

NOTE: Further information on the use of these symbols will be found in "Welding Symbols and Instructions for Their Use," published by the American Welding Society, New York, price 25 cents.



## **TITLE 32—NATIONAL DEFENSE**

### **Chapter IX—Office of Production Management Subchapter B—Priorities Division**

#### **Part 944—Regulations Applicable to the Operation of the Priorities System**

##### **PRIORITIES REGULATION NO. 3—TO PROVIDE FOR THE USE OF REVISED PREFERENCE RATING CERTIFICATES AND PRESCRIBE THE MANNER OF APPLICATION OF RATINGS ASSIGNED THEREBY**

Assignment and extension of individual preference ratings has been simplified and made more uniform by Priorities Regulation No. 3 (given in full immediately following this discussion), announced January 12 by Donald M. Nelson, Director of Priorities.

Beginning February 2, 1942, individual preference ratings of the type which has heretofore been assigned on PD-1 and PD-3 forms may be extended to suppliers and sub-suppliers of the producer who receives the rating by a simple endorsement on purchase orders, like that now used for extension of limited blanket ratings and ratings under the Production Requirements Plan.

Under an arrangement between the Director of Priorities and the Army and Navy Munitions Board, ratings assigned by Army and Navy field officers will no longer be limited to items appearing on the Army and Navy Priorities Critical List. However, under Regulation No. 3, extension of individual ratings will be limited to material which will be physically incorporated in the items originally rated.

Two new forms of Preference Rating Certificates, PD-1A and PD-3A, will replace the present forms, PD-1 to PD-5 inclusive, for assignment of individual ratings. Use of the new forms will be optional on and after February 2 and mandatory on and after March 1.

Form PD-1A which will replace Form PD-1 is a simplified blank to be used in making specific applications for materials or supplies when general preference orders do not provide the required priority assistance. When PD-1A applications are approved by the OPM Priorities Division, rat-

ings will be assigned on the form itself. A similar procedure has been standard for some months. Form PD-2, which was formerly used to assign ratings in response to applications on PD-1 forms, will disappear and will not be replaced.

Preference ratings assigned to applicants who use Form PD-1A may be extended on and after February 2 to suppliers and subsuppliers of the applicant by the prescribed endorsement on purchase orders, signed by a duly authorized representative of the company making the extension, and will not require a countersignature from any government officer. Heretofore, preference ratings assigned on PD-1 forms have not been extendable under any circumstances.

Form PD-3A will be used for all applications for ratings in connection with orders from the Army, Navy, Coast Guard, Maritime Commission, Coast and Geodetic Survey, Panama Canal, National Advisory Committee on Aeronautics, Civil Aeronautics Authority, Office of Scientific Research and Development, Procurement Division of the Department of the Treasury, Surplus Marketing Administration of the Department of Agriculture, and contracts or purchase orders from foreign governments. It will replace Forms PD-3, PD-4, and PD-5.

Ratings assigned on Form PD-3A may also be extended to suppliers and subsuppliers without countersignature. Ratings which have been assigned on PD-3 forms were formerly extendable without countersignature only if the amount of the order involved was less than \$500.

When an individually rated order is served upon a supplier by the original applicant under the new procedure, the rating may be extended by the supplier, by his suppliers and subsuppliers to obtain any material which will be delivered to the original applicant in accordance with the rating, but neither the applicant, his suppliers or subsuppliers may use the rating to obtain machinery or capital equipment which they use in fabricating parts to fill the order. If producers who have been assigned a rating on a PD-1A form need machinery or capital equipment for this purpose which they cannot obtain without priority assistance, they must apply for a separate preference rating on another PD-1A form. Prime contractors who need machinery or equipment to be used exclusively in filling Army or Navy orders may be given a rating for use in obtaining such machinery or equipment on PD-3A forms.

Another important change made by Priorities Regulation No. 3 allows the recipient of an individual rating, his suppliers and subsuppliers to employ the rating for replacement in inventory of materials used in filling the rated order, provided such replacement does not increase inventories above a practicable working minimum.

If the materials to be replaced are in whole or in part manufactured, processed, assembled or otherwise physically changed by the supplier, the rating must be extended while the materials are in process of fabrication. For materials which are not processed or otherwise changed by the supplier, extension of the rating may be deferred up to three months, until an order can be placed for the minimum quantity procurable on customary terms. This provision is primarily for the benefit of wholesalers and distributors, enabling them to group their own orders while making deliveries in small quantities.

The new regulation also allows a supplier or subsupplier who has received two or more purchase orders bearing ratings of the same grade to include in a single purchase order or "basket," within the limitations which have been indicated above, any or all of the material which he requires to make deliveries in accordance with the rated purchase orders which have been served upon him. In such case, he must specify in the certification on his own purchase order all of the Preference Rating Certificate form numbers and serial numbers referring to the orders in connection with which he is extending the ratings.

All persons who receive or extend preference ratings assigned on PD-1A and PD-3A forms must keep records as prescribed by Priorities Regulation No. 1 and make such reports as may be required by the Director of Priorities. Use of PD-3A forms may also be subject to such further requirements as may be set forth by the Army and Navy Munitions Board with the concurrence of the Director of Priorities.

Preference Rating Certificate Form PD-1A may be reproduced in blank by or for any user, but Preference Rating Certificate Form PD-3A may not be reproduced. PD-1A forms may be procured from the Priorities Division of the Office of Production Management either in Washington or in field offices. PD-3A forms may be procured from contracting and procurement officers of the Army and Navy.

Copies of the new forms will not be distributed to applicants by the Office of Production Management or the Army or Navy until immediately before February 2, 1942.

**PRIORITIES REGULATION NO. 3**

The following Regulation is issued by the Director of Priorities to promote the defense of the United States and for the purpose of improving and facilitating the operation of the Priorities System.

944.23 (a) *Adoption of Revised Forms of Preference Rating Certificates.* On and after February 2, 1942, preference ratings to be assigned by Preference Rating Certificates *may* be assigned and on and after March 1, 1942, *shall* be assigned, in the manner and subject to the provisions hereinafter set forth, by revised forms of Preference Rating Certificates hereby designated as Preference Rating Certificate PD-1A and Preference Rating Certificate PD-3A, copies of which are hereto attached and made a part hereof, and hereby adopted in place of the Preference Rating Certificates Forms PD-1, PD-2, PD-3, PD-4 and PD-5; *provided*, that all Preference Rating Certificates Forms PD-1, PD-2, PD-3, PD-4 and PD-5 duly issued prior to March 1, 1942, are valid and shall continue valid in effect until termination or expiration by the terms thereof or by the circumstances or conditions of their application, or until hereafter cancelled, modified, changed or amended by the Director of Priorities.

(b) *Categories of Use of Prescribed Preference Rating Certificates.*

(1) Preference Rating Certificate PD-3A shall be used to assign preference ratings, where appropriate, to deliveries under contracts or purchase orders of the Army, Navy, Coast Guard, Maritime Commission, Coast and Geodetic Survey, Panama Canal, National Advisory Committee on Aeronautics, Civil Aeronautics Authority, Office of Scientific Research and Development, Procurement Division of the Department of the Treasury and Surplus Marketing Administration of the Department of Agriculture contracts or purchase orders of foreign governments; and such other contracts or purchase orders as may be prescribed from time to time.

(2) Preference Rating Certificate PD-1A shall be used to assign, where appropriate, preference ratings to deliveries under all other contracts and purchase orders.

(c) *Extension of Preference Ratings to Deliveries Under Contracts and Purchase Orders and Subcontracts and Suborders.*

(1) Preference ratings assigned by Preference Rating Certificates PD-1A and PD-3A may be extended to deliveries under contracts and purchase orders and subcontracts and suborders by endorsing on the purchase order or other equivalent document furnished to the Supplier or Subsupplier a Certification in the form prescribed by the appropriate certificate, filled in and manually signed by an official of the purchasing company duly authorized for such purpose.

- (2) In cases where Preference Rating Certificates PD-3A issue under letters of intent and therefore no contract number can be inserted in the space provided in the Certification form, reference to a footnote addition shall be inserted and in such footnote the Supply Arm or Bureau of the Army or Navy or other government agency issuing the letter of intent and the date of such letter, together with any identification symbol on such letter, shall be stated.
- (3) A Supplier or Subsupplier who has received two or more contracts or purchase orders bearing ratings of the same grade originally assigned by Preference Rating Certificate PD-1A and PD-3A, may include in a single contract or purchase order, and (within the limitations of (e) hereof) may extend such rating to, any or all of the material which he in turn requires to make delivery in accordance with such contracts or purchase orders or to replace in inventory material so delivered, but must specify in the Certification endorsed on such single purchase order or equivalent document all of the Preference Rating Certificate Form Numbers and corresponding Serial Numbers of the ratings which have been so received by him and pursuant to which he is extending the rating. All spaces must be filled in where applicable.
- (d) *False Statements.* The execution and transmission of the Certification above set forth to a Supplier or Subsupplier shall be deemed a representation to the Office of Production Management for the purpose of Section 35(A) of the Criminal Code (18 U.S.C. 80), which makes it a criminal offense to make a false statement or representation to any Department or Agency of the United States as to any matter within its jurisdiction.
- (e) *Restrictions on Extension of Ratings Assigned by a Preference Rating Certificate PD-1A or PD-3A.*
- (1) A Supplier or Subsupplier may extend the preference rating only to:
- (i) deliveries of material which will be physically incorporated into material to be ultimately delivered by him or by another Supplier to the original recipient of the preference rating, or to deliveries of material which will itself be ultimately delivered by him or by another Supplier to the original recipient of the preference rating, or which will be used, within the limitations of paragraphs (e) (1), (2) and (3) hereof, to replace in inventory material so delivered;
  - (ii) material which is neither greater in quantity nor to be delivered on dates earlier than required to make on schedule a rated delivery or, within the limitations of (2) and (3) below, to replace

in inventory material so delivered. Material shall not be deemed to be so required if the rated delivery may be made and a practicable working minimum inventory thereof still retained; and if, in making such delivery, the inventory is reduced below such minimum, the rating may be extended only to the extent necessary to restore the inventory to such minimum.

(2) A Supplier or Subsupplier who supplies material which he has in whole or in part manufactured, processed, assembled or otherwise physically changed, may not extend the rating to restore his inventory to a practicable working minimum unless he extends the rating before completing the rated delivery which reduces his inventory below such minimum.

(3) A Supplier or Subsupplier who supplies material which he has not in whole or in part manufactured, processed, assembled or otherwise physically changed may, in restoring his inventory to a practicable working minimum, defer extensions of the rating originally assigned by a Preference Rating Certificate PD-1A or PD-3A for such material until he can place a purchase order or contract for the minimum quantity procurable on his customary terms; *provided*, that he shall not defer the extension of any rating for more than three months before he becomes entitled to apply it.

(4) The extension of preference ratings assigned by Preference Rating Certificate PD-3A may be made subject to such additional provisions and conditions as may from time to time be prescribed by the appropriate Supply Arm or Bureau of the Army or Navy, with the approval of the Army and Navy Munitions Board and of the Director of Priorities.

(5) Any Supplier or Subsupplier who extends the preference rating shall be subject to all of the terms and conditions of this Regulation.

(f) *Records, Audit and Inspection, and Reports.* Any person who applies for or extends a preference rating or to whom a preference rating certificate is issued, and any Supplier or Subsupplier who receives a contract or purchase order bearing a rating, shall maintain such records and shall be subject to such audit and inspection as are provided by Priorities Regulation No. 1 as the same may be amended or supplemented from time to time; and shall make such reports as may be required by the Director of Priorities from time to time hereafter.

(g) *Violations.* Any person who wilfully violates any provision of this Regulation or of Preference Rating Certificates PD-1A or PD-3A or who, by any act or omission, falsifies records to be kept or information to be furnished pursuant to this Regulation, may be prohibited from receiving

further deliveries of any material subject to allocation, and such further action may be taken as is deemed appropriate, including a recommendation for prosecution under Section 35(A) of the Criminal Code (18 U.S.C. 80).

(h) *Reproduction of Forms.* Preference Rating Certificate Form PD-1A may be reproduced in blank by or for the user thereof but Preference Rating Certificate Form PD-3A may not be reproduced. Preference Rating Certificate Form PD-1A may be procured from the Priorities Division of the Office of Production Management or any of the field offices thereof; Preference Rating Certificate Form PD-3A may be procured from the duly authorized contracting and procurement officers and inspectors of the Army and Navy.

(i) *Effective Date.* This Regulation shall take effect the 2nd of February, 1942.

(P.D. Reg. 1 Amended, Dec. 23, 1941, 6 F.R. 6680; O.P.M. Reg. 3 Amended, Sept. 2, 1941, 6 F.R. 4865; E.O. 8629, Jan. 7, 1941, 6 F.R. 191; E.O. 8875, Aug. 28, 1941, 6 F.R. 4483; sec. 2(a), Public No. 671, 76th Congress, Third Session, as amended by Public No. 89, 77th Congress, First Session.)

Issued this 12th day of January, 1942.

(signed)

J. S. KNOWLSON

*Acting Director of Priorities*